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Decision Support Systems

Partel implementation

Master's Thesis in Information Systems
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Abstract

Subject: Information Systems	
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Abstract:

This paper examines how the theories about the decision-making process, information systems and decision support systems can be applied in a small scale, low cost research project and deliver value. The aim was to use existing data from a small internet service provider called Partel to develop a dedicated system that could aid in the decision-making process.

The theoretical foundation of this paper is derived mostly from the thoughts and research done by Herbert A. Simon and the follow-up research done based on his findings. The focus point of the theories found in this paper is used to argue for the implementation and use of different systems to aid in the decision-making process of organizations. The theories clearly point out the inability of humans to comprehend large amounts of raw data, and how different types of systems can be used to negate this weakness and allow for more accurate decisions to be made.

The result of the research was a rudimentary decision support system that enables a user to easily access relevant data regarding a specific copper cable network and use these data to make informed decisions. The developed system is dedicated to aid in very specific decision-making processes and is designed with a few specific features in mind.

Keywords: Decision support systems, decision-making process, information system,

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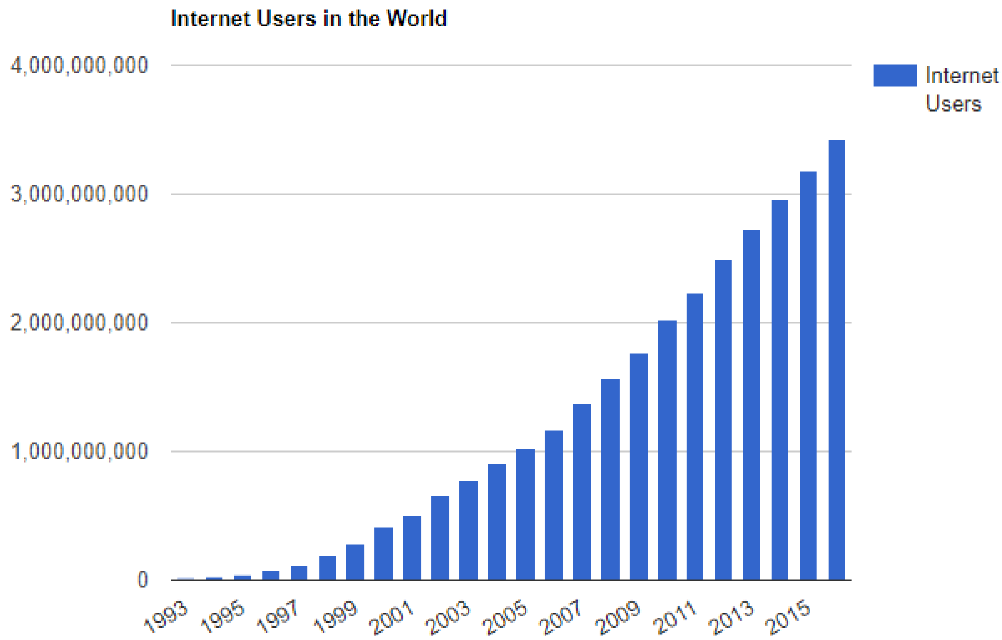
1. Introduction

Background of the study

Today's modern society is becoming more and more dependent on the internet. The internet is a world-wide computer network that can be accessed from a plethora of devices, such as computers, mobile phones, game consoles etc. A device can access the internet either via fixed networks such as copper cable and optical fiber cable networks, or via wireless networks which include cell towers, satellites or WIFI access points.

According to the Internet live stats - internet usage & social media statistics, which is a website dedicated to tracking the growth and usage of the internet across the world, roughly 40% of the world's population has access to the internet in 2017, compared to less than 1% in 1995. The growth of the internet is caused by the ever-increasing supply of and demand for information- and communication technology, or ICT for short. Information- and communication technology has changed the world in many ways, not only is it changing how the world communicates, but it is also the driving force behind technical and economic development across the world.

As displayed in p*icture 1* and p*icture 2*, Internet users in the world per year acquired from Number of internet users (2016) - internet live stats, internet usage has seen a massive increase since it was first introduced. This growth has mainly happened in the developed countries, where many developed countries in Europe have an internet penetration percentage of over 80%, and all the Nordic countries have a penetration of above 90%.



Picture 1 Number of internet users in the world per year

Year	Internet Users**	Penetration (% of Pop)	World Population	Non-Users (Internetless)	1Y User Change	1Y User Change	World Pop. Change
2016*	**3,424,971,237**	46.1 %	7,432,663,275	4,007,692,038	7.5 %	238,975,082	1.13 %
2015*	**3,185,996,155**	43.4 %	7,349,472,099	4,163,475,944	7.8 %	229,610,586	1.15 %
2014	**2,956,385,569**	40.7 %	7,265,785,946	4,309,400,377	8.4 %	227,957,462	1.17 %
2013	**2,728,428,107**	38 %	7,181,715,139	4,453,287,032	9.4 %	233,691,859	1.19 %
2012	**2,494,736,248**	35.1 %	7,097,500,453	4,602,764,205	11.8 %	262,778,889	1.2 %
2011	**2,231,957,359**	31.8 %	7,013,427,052	4,781,469,693	10.3 %	208,754,385	1.21 %
2010	**2,023,202,974**	29.2 %	6,929,725,043	4,906,522,069	14.5 %	256,799,160	1.22 %
2009	**1,766,403,814**	25.8 %	6,846,479,521	5,080,075,707	12.1 %	191,336,294	1.22 %
2008	**1,575,067,520**	23.3 %	6,763,732,879	5,188,665,359	14.7 %	201,840,532	1.23 %
2007	**1,373,226,988**	20.6 %	6,681,607,320	5,308,380,332	18.1 %	210,310,170	1.23 %
2006	**1,162,916,818**	17.6 %	6,600,220,247	5,437,303,429	12.9 %	132,815,529	1.24 %
2005	**1,030,101,289**	15.8 %	6,519,635,850	5,489,534,561	12.8 %	116,773,518	1.24 %
2004	**913,327,771**	14.2 %	6,439,842,408	5,526,514,637	16.9 %	131,891,788	1.24 %
2003	**781,435,983**	12.3 %	6,360,764,684	5,579,328,701	17.5 %	116,370,969	1.25 %
2002	**665,065,014**	10.6 %	6,282,301,767	5,617,236,753	32.4 %	162,772,769	1.26 %
2001	**502,292,245**	8.1 %	6,204,310,739	5,702,018,494	21.1 %	87,497,288	1.27 %
2000	**414,794,957**	6.8 %	6,126,622,121	5,711,827,164	47.3 %	133,257,305	1.28 %

Picture 2 Number of internet users in the world per year

The amount of information that is being transferred for private usage, but also for government and corporate usage, is massive and this puts a strain on existing infrastructure solutions that were not designed for the high data traffic required by most ICT services in use today. To keep up with the demand, internet service providers, or ISPs, are investing in modern optical fiber infrastructure that can support the increased demand. Internet service providers are businesses that focus on delivering internet connectivity and services to their customers, which means that these businesses must make sure that their infrastructure networks are capable of meeting the data traffic needs of their customers.

Keeping up with the growing demand is a continuous process, which can be very costly as old copper cable networks are not capable of meeting the demand of the customers. The larger internet service providers have the economic muscles to meet the upgrading costs, while smaller actors on the market might have to evaluate how and where they invest their resources to best suit their businesses.

The focus of this research will be a small internet service provider in the south-west of Finland. The main goal of the research was to analyze the situation and with the help of existing data and data analysis, aid the company in making decisions regarding upgrading projects.

The case company – Partel

The company that was the target for this research is an internet service provider called Partel that operates its business in the small town of Pargas in the Finnish archipelago. The company was founded back in 1894 as a local phone company, providing the local population access to the phone network of the day. The company had a revenue of 2.9 million euros in 2016. (Årsberättelse 2016 – Partel.)

Over the years, Partel has evolved with the market to an internet service provider that provides both the infrastructure solutions to enable access to the internet and phone network, and other services that support their core business. These services include Cable-TV, call service for companies and customer support from their store in Pargas.

Partel's situation in the autumn of 2014, when the initial plans for the research started, was that the company knew how to reach the more densely populated areas, as large construction investments could easily be funded by finding willing customers who were prepared to pay the initial fees to begin construction. The problem arose when Partel started analyzing the customer demographic of the less densely populated areas of Pargas. There was a large customer base that lived in rural areas where the normal return on investment models did not work and it was difficult the company to make estimations in these areas based on the existing models.

The company core vision is to be a company for the population of Pargas and leaving a large number of customers without internet services was not acceptable according to the CEO. The research was focused on the rural areas of Pargas and attempted to come up with a suitable methodology to enable Partel to better plan construction projects in rural areas.

The objectives of the study

The objective of the study was loosely defined as "*how can I as an information systems student aid Partel in their decision-making process?*". The CEO wanted a method for improving the decision-making process regarding copper cable and optical fiber network projects. The task would be to look at the data of already existing copper cable networks and estimate what kind of information could be retrieved and how it could be used.

Based on this loosely defined objective and the situation Partel was in, the following research objectives were defined:

- How can information systems aid in the decision-making process?

  Partel had a large amount of information regarding their cable networks and customers. The information was scattered across several different databases, mapping tools and *AutoCAD* maps, making it very difficult to use them independently or together.
- Can the data gathered by Partel aid in the decision-making process?

  As Partel had no centralized tool for tackling issues related to the decision-making process, it was decided to focus the research on how to aid Partel in the decision-making process by using existing data.
- Can a low-cost decision support system be developed based on the existing data?

  Partel is a very small internet service provider that cannot afford to invest in decision support systems developed by larger companies on the market. One of the goals for the research was to attempt the development of a support system for Partel.

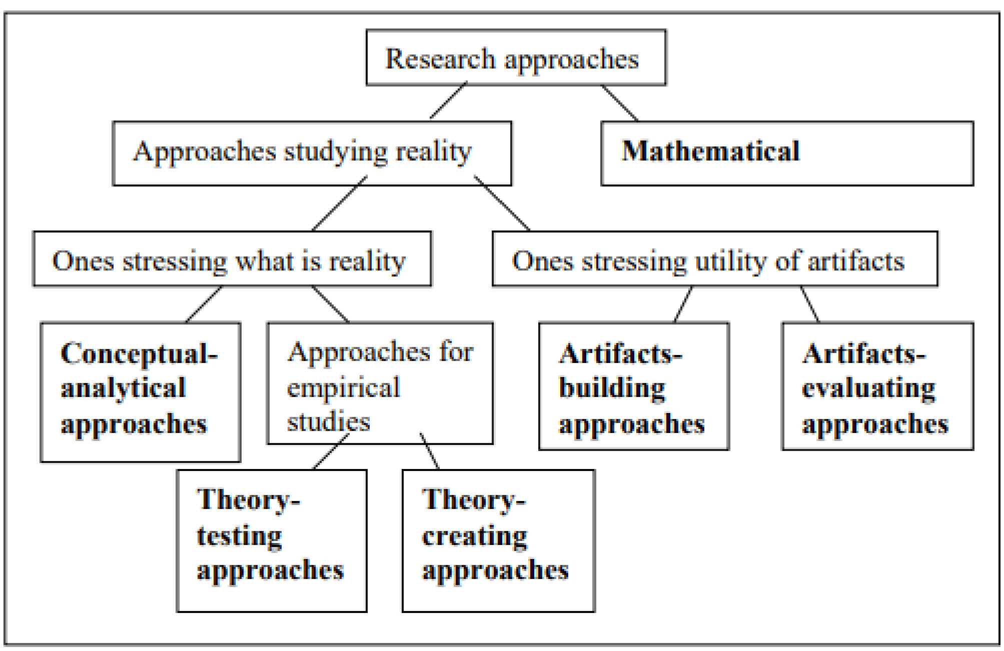
The highest prioritized objective was the development of a rudimentary decision support system that could enable Partel to make decisions based on data, rather than using subjective opinions regarding copper cable and optical fiber construction projects. The first step was to research the existing data that Partel had gathered and evaluate if the objective was viable.

Research methodology

The purpose of the research methodology chapter is to define and explain the research process. This will be done using the theories presented by *Pertti Järvinen* in his texts "*On a variety of research output types (2004)*" and "*The stepwise algorithm for selecting an appropriate research method (2001)*". (Järvinen, 2001; Järvinen, 2004)

The research methodology applied for this research falls under the main research method *approaches studying reality* and the sub-methodology of *artifacts-evaluating approach* presented by Järvinen (2004) in *picture 3*. The output for the proposed research methodology is defined by Järvinen as:

The utility (efficiency, effectiveness etc.) of a certain artifact (or prescriptive model or normative method) is evaluated by using some criteria.

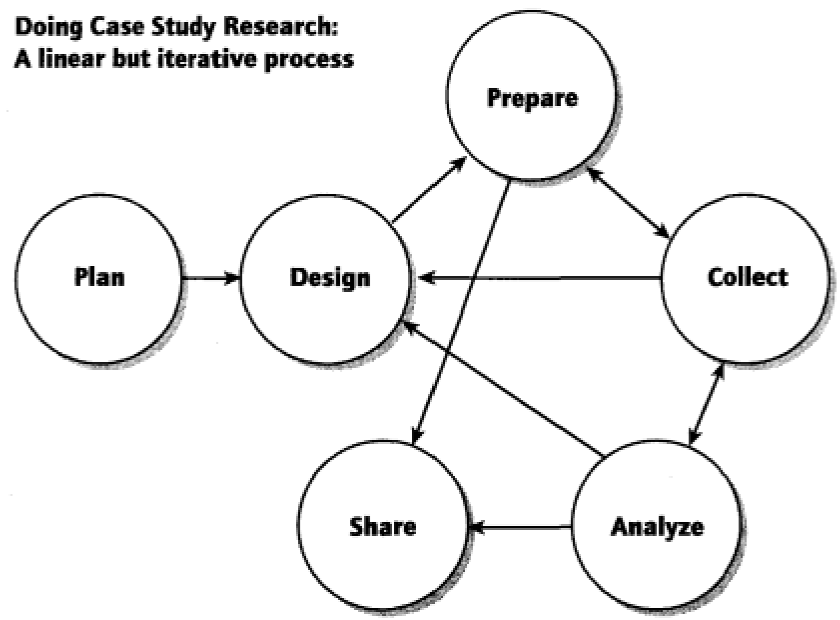


Picture 3 Pertti Järvinen Taxonomy of research methods

This output definition fits the research questions that lay the foundation for this paper:

- How can information systems aid in the decision-making process?
- Can the data gathered by Partel aid in the decision-making process?
- Can a low-cost decision support system be developed based on the existing data?

Developing the research methodology, Robert K. Yin examines this topic further in his book *Case Study Research - design and methods (2009)*.



Picture 4 Doing Case Study Research: A linear but iterative process (Yin, 2009)

Yin (2009) describes the research process in *picture 4*, were each research starts with a plan, and is continuously passing through four phases until the process is completed in the *Share* phase. The process described by Yin (2009) fits the approach used to develop the decision support system for Partel.

The research plan was made in close collaboration with Partel. Different research approaches and potential outputs were explored. The key issue identified by Partel was how to expand the optical fiber network to the rural and less densely populated areas of Pargas, as all indications pointed towards higher costs with lower returns of investment. The conclusion from the planning phase was that the research would attempt to use existing network and customer data to analyze the situation and perhaps find a solution that could aid in the decision-making process for Partel. The output should be a decision support system in Microsoft Excel that could aid in Partel's decision-making process.

The *design* phase was continuously revisited as more and more data became available. The first iteration of the design phase involved setting up a rudimentary plan for what information would be needed to deliver value, such as number of customers, cost structures and technical information regarding the networks. The early forms of the design phase were focused on setting up data and connecting information to each other, while the later phases of design focused heavily on displaying information and the user interface design.

The *prepare* phase consisted of using mock-data that was similar to data found in the databases. This was to verify that the possible design would work for the type of information retrieved during the *collect* phase. The prepare phase also involved earmarking data from different systems to the different data sheets that would be used, creating a system for how collected and processed data would be inserted into the Excel sheets as it became available.

Collect and *analyze* consisted of gathering all the available data and process it into a format that could be used by Excel. This process was continually repeated, as data from one source had to be processed and compared to other sources that contained the same type of information and evaluate which data source was most reliable. The evaluation process was mostly focused on determining the actual geographical locations of the different parts of the network and determining cable distances. The research approach followed Yin´s (2009) visualization in *picture 4*, as the design and prepare phases were revisited as new information became available.

The *share* phase was done as each Excel file was completed. This occurred several times for the first network file, as Partel's head of networks evaluated how the tool worked as part of his tasks. This is where the practical research differs from Yin's 2009 visualization, as the final product effectiveness could only be fully determined once it was completed. When the evaluation was done, and the new requirements were listed, the *design* phase would be revisited to develop the next version.

This process was repeated several times as the use-case was developed further by Partel. The final requirements for the decision support system was heavily focused on displaying deconstruction costs for each network. Rather than estimating the cost of upgrading the network to optical fiber, vital data such as geographical locations and cable distances was retained in the final version, as this would aid in the decision-making process. (Järvinen, 2001; Järvinen, 2004; Yin, 2009)

Structure of the thesis

This thesis consists of a short introduction to the topic, a literature review presenting the theories and models used in the thesis, presentation of the practical research methods, presentation of the findings and a summary.

The introduction presents the reason for the thesis, by reviewing the current trends in internet usage and why internet service providers need to commit to upgrading the existing networks to handle the growing demand from customers. The introduction will also present the case company Partel and the research objectives that were determined with Partel. Finally, the research methodology will be briefly presented.

The literature review will present the different theories and models that form the foundation for this thesis, with the main focus being placed on the decision-making process, decision support systems and information systems.

In the practical review, the research approach will be presented, including tools that applied to this specific case, a brief overview of the data available at the start of the research, mathematical formulas, and set formulas given by Partel to be used as references. All the data in this paper is mock data, as the research was done under a non-disclosure agreement with Partel.

The last chapters will summarize the results from the research and identify possibilities that were discovered and flaws and limitations to the implementation.

2. Model-based approach for DSS design

The theories in this thesis paper are based on the three major theoretical fields:

- Decision-making
- Information Systems
- Decision support systems

The three theoretical fields were chosen based on their relevance to the practical aspects of this research paper. The main challenge from a research point of view was the lack of existing support systems to aid Partel in the decision-making process. The problems related to the decision-making process will be addressed in this research paper using theories from the Nobel Prize winning political scientist Herbert A. Simon.

Herbert Alexander Simon was an American economic- and political scientist who was born in 1916 and passed away in 2001. Simon received several awards for his research, among these were the Turing Award in 1975 and the Nobel Prize in economics in 1978. Simon focused his research on the decision-making process, particularly within organizations, and he was one of the pioneers who laid the groundwork for new research areas such as artificial intelligence, decision-making and problem-solving, information systems and decision support systems. Lewis (1991) noted that at the time, 75% of authors of information systems manuals had adopted Herbert A. Simon's theories as a core in their manuals. (Lewis, 1991)

Decision-making

Decision-making is defined in the business dictionary as:

> *"The thought process of selecting a logical choice from the available options. When trying to make a good decision, a person must weigh the positives and negatives of each option and consider all the alternatives. For effective decision-making, a person must be able to forecast the outcome of each option as well, and based on all the items, determine which option is the best for that particular situation."*

Making decisions is part of the human experience, and there are varying estimations regarding how many decisions a person needs to make during a day. The number of decisions vary depending on how one defines decision-making, but the fact is that a person needs make a plethora of decisions throughout a single day. Some decisions can be trivial, while others can be life changing.

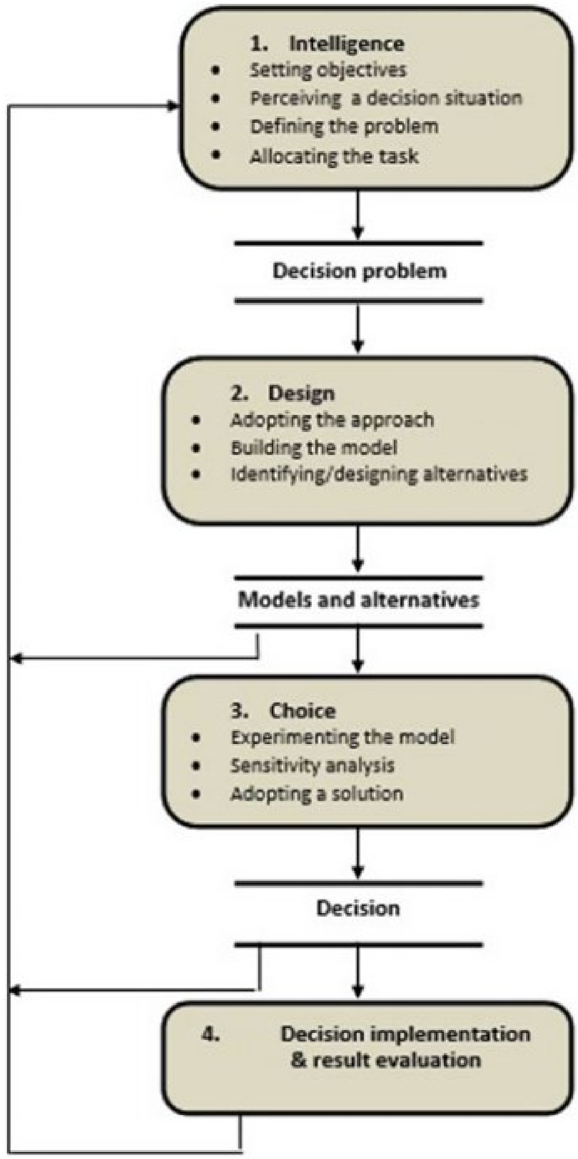
Making informed decisions is the common definition of a rational person, *Parnas and Clements* (1986) defined in their journal paper *"A Rational Design Process: How and Why to Fake It"* a perfectly rational person as;

> *"As someone who always has a good reason for what he does. Each step taken can be shown to be the best way to get to a well-defined goal."* (Parnas & Clements, 1986)

Parnas and Clements (1986) point out that the definition of how a rational person goes about making decisions is not the norm, and it is rare for decisions to be made with all the information required. It has been proven that people are unable to fully comprehend the information required to make rational decisions in complex cases, even when a person has access to all the relevant information. There is a need for a process to aid in the decision-making process. (Druzdzel & Flynn, 2002; Langley, Mintzberg, Pitcher, Posada, & Saint-Macary, 1995; Lewis, 1991; Parnas & Clements, 1986; Herbert Simon, 1962; Herbert A. Simon, 1960, businessdictionary.com)

According to Pomerol and Adam (2008), Herbert Simon is among the most influential and important contributors to the field of organizational theory. Herbert Simon viewed the decision-making processes as a form of information processing, with the goal of achieving a certain result. According to Simon (1960), the result would be achieved based on a process consisting of three, and later four steps. (Campitelli & Gobet, 2010; Pomerol & Adam, 2008; Simon, 1960; Herbert A. Simon, 1977)

- The intelligence step consists of activities such as: Setting the objectives of the process, collecting and analyzing data in order to determine a decision problem, and finally defining or stating the problem.
- The design step is where different possible courses of action are defined, where models are built and possible solutions to the problem are evaluated.
- The choice or selection step is where viable decisions and implementations are reviewed for realizing the solution.
- The Implementation and review step was introduced by Herbert Simon in the late 1970s. This step is where the solution was implemented, and the results of the outcome were reviewed.



Picture 5 Simon's process model of decision making (Filip, Zamfirescu, & Ciurea, 2017)

Filip et al. (2017) points out that there are differences between decision-making and decision-taking, however, these terms are often used interchangeably. The difference between the two terms is that decision-making is the result of the process defined above, while decision-taking is the act where an individual or a group takes a decision for which they are accountable for the outcome.

The goal of the decision-making process is to reach a *completely structured* problem. A completely structured problem is when all the possible alternative decisions have been explored and evaluated before the decision is made. Until a problem has been completely structured, it is either in an *unstructured* or *semi-structured* state. (Filip, Zamfirescu, & Ciurea, 2017)

Programmable and non-Programmable decisions

In their book *Computer-supported collaborative decision-making* Filip et al. (2017) explores the concept of decision making further, by looking at the concept of Programmable and non-programmable decisions, Simon (1977) stated that:

> *"Decisions are programmed to the extent that they are repetitive and routine, to the extent that a definite procedure has been worked out for handling them so that they don't have to be treated from scratch each time they occur".*

Simon also stated that non-programmable decisions are:

> *"To the extent that they are novel, unstructured and unusually consequential."*

The idea of using computers for problem-solving was presented by Simon in the 1970s, and the thought was that once a process for solving a problem was developed, the same method could be applied again to solve similar problems. A problem that can be completely defined can be programmed into a computer and can then be used for problem and decision-making processes in the future. The difficulty with decision-making is when a completely new problem is encountered and no existing methods for solving it are viable. This is what Simon (1977) and Filip et al. (2017) referred to as *Nonprogrammable* decisions. (Filip et al., 2017; Simon, 1977)

The concept of programmable and non-programmable decisions is the core of organizational learning and the foundation of decision support systems. Munier (1998) explored the concept of programmable and non-programmable decisions, and with experimental observations determined the difficulties of the concept. (Munier, 1998; Herbert A. Simon, 1996)

Human decision-making and its constraints

The human decision-making process has several limits and constraints and Simon (1962) likened the process to a maze. Just as solving a new maze, the process requires a great deal of trial and error. Throughout our lives, we humans must make decisions. Every new decision that we face will fall within the previously mentioned categories *completely structured, semi-structured or unstructured*. A variety of paths needs to be tried to solve a decision-making problem, paths are pursued until they are eventually abandoned, or the process was completed, and a decision was made. The more difficult a problem is, the more paths of trial and error is expected to take place. The research concluded that the human problem-solving and decision-making process comes down to trial, error and selectivity. The more a person engages in these activities, the more proficient that person becomes at these specific tasks. Simon (1962) draws parallels between solving puzzles, playing chess and other cognitive activates, were a person becomes more proficient at them the more they practice. (Filip et al., 2017; Simon, 1962)

How well a human makes decisions in certain situations is based on several different factors according to Holsapple and Whinston (1996). *Cognitive limits* are limitations that exist based on the quality and quantity of data available, these limitations also include the different methods used for the decision-making process and the experience of the individual who makes the decision. *Costs* limitation refers to the cost of acquiring the assistance and knowledge from another source. It is common for companies to hire consultants who can aid in the decision-making process. *Temporal* limitations are based on time, as situations sometimes requires decision to be made quickly. *Communication* is a vital part of the decision-making process when more than one person needs to be part of the decision-making process. When several people with different backgrounds, knowledge and subjective thoughts are part of decision-making process, communication can be one of the most difficult parts of the process

The last constraint mentioned by Holsapple and Whinston, (1996) is the lack of *trust* in the decision-making process. A decision can be based on gut-feeling rather than facts if the decision maker does not trust the information and models available to him. (Holsapple & Whinston, 1996; Simon, 1960; Simon, 1996)

Organizational decision-making process

The organizational decision-making process requires the attention of multiple individuals due to the amount of decisions that needs to be made. As previously discussed in this paper, the research points to the fact that we humans are not good at making rational decisions on our own. Our decision-making processes are not solely based on facts and rational decisions, but also on subjective factors such as education, upbringing and our position within the decision-making process, and this will directly affect the individuals decision-making process on and organizational level as well. Mykkänen and Tampere (2014) noted in their research paper *Organizational Decision Making: The Luhmannian Decision Communication Perspective* that engineering-based organizations decision-making process is strongly based in relevant information and facts. (Carley & Behrens, 1999; Mykkänen & Tampere, 2014; Parnas & Clements, 1986; Simon, 1996)

The daily work within any organization is full of decisions, meaning that the minor day to day decisions are not considered decisions on an organizational level. The definition of a decision within an organizational structure is reserved for the big decisions where the outcome can affect the whole organization. (Carley & Behrens, 1999; Mykkänen & Tampere, 2014; Simon, 1977)

The organizational decision-making process is built upon several layers of information, ranging from messages and communication between individuals and departments, to databases and information systems. Different decision makers within an organization can have access to varying types and structure of information regarding a topic and this information needs to be shared among other decision makers in such a way that the content can be grasped regardless of their background. This means that in a world of information, an organization's most critical decision-related task is not to generate or gather more information, but to manage the existing and new information in such a way that it does not exceed the organization's ability to process the information. Mykkänen and Tampere (2014) concluded their study by stating that effective communication can be considered the backbone of the organizational decision-making process. The success of an organizational decision is dependent on the accuracy and availability of information to the organization's decision makers. (Carley & Behrens, 1999; Langley et al., 1995; Mykkänen & Tampere, 2014; Parnas & Clements, 1986; Pomerol & Adam, 2008; Simon, 1977)

Information systems

The term in*formation system* can historically be linked to the usage of computers within organizations. The definition of information systems is still vague despite all the available research, literature and implementations. There are several very similar definitions of information systems and one is found in the *Committee on National Security Systems* glossary (CNSS, 2015):

Information systems (IS), a distinct set of information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information. Information systems also include specialized systems such as industrial/process control systems, telephone switching and private branch exchange systems, and environmental control systems.

Wognum et al. (2004) defines the purpose of information systems as a system to support organizations in processing and managing information. The following examples of systems are considered as information systems:

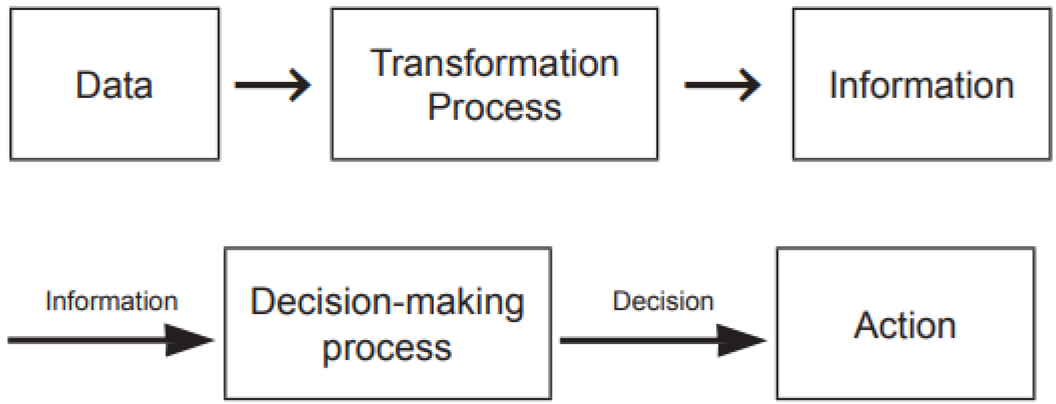
- Enterprise Resource Planning systems (ERP)
- Customer Relationship Management systems (CRM)
- Supply Chain Management systems (SCM)
- Product Data Management systems (PDM)
- Decision Support Systems (DSS)

Boell and Cecez-Kecmanovic (2015) concluded that information systems are general made up of a variety of information technologies, such as computers, mobile devices, databases, software, networks and communication systems. The definitions, components, purpose and subsystems related to information systems vary depending on the literature, but the main task of an information system can be defined as a system made up of several components that stores and processes information. (Boell & Cecez-Kecmanovic, 2015; Kamel, Lakhder, & Ammar, 2012; Nickerson, 2000; Wognum, Krabbendam, Buhl, Ma, & Kenett, 2004).

The Role of Information systems

Information systems in their most basic form are networks constructed from software and hardware that are used by organizations to collect, store, process, filter and distribute data. (Bourgeois, 2014)

The terms data and information are used extensively in this paper and although these terms are often used indiscriminately, the terms do have different meanings. Data is a raw value, for example an attribute such as an organizations invoice. Information is data that has been processed so that it can be used to aid in the decision-making process. Alcami and Carañana (2012) suggest that one should interpret the relationship between data and information in the same way as the relationship between raw materials and a finished product. This relationship is represented in the *picture 6* below:



Picture 6 Relationship between data and information

The process of transforming data into useful information could be considered the core of information systems. The transformation process varies depending on the system and the process is designed to meet a specific need for the organization where the information system is being used. (Alcami & Carañana, 2012; Bourgeois, 2014; Harsh, 2014)

Organizations and information systems

Information systems aid in the different organizational data management processes, and what features a system has, depends on the organization's processes and who the primary users are. Organizations that invest in the development and acquisition of information systems are normally subject to organizational changes. The processes and possibilities delivered by an information system can often require an organization to change its processes to better make use of the information. The change can either come as part of a planned process change, or as an outcome of the new information available to the organization. (Boell & Cecez-Kecmanovic, 2015; Halonen, 2007; Hardcastle, 2008; Harsh, 2014)

According to Halonen (2007), one of the major issues that organizations face as a result of an information system implementation is something that was also mentioned by Holsapple and Whinston (1996), which is *trust*. Trust is important from a system implementation perspective, as the users need to trust the information that is delivered by the system. Halonen mentioned that information system project failure rates can be as high as 80 percent, this is a very high number considering the large amount of resources required to attempt a system implementation. The reasons for project failures can vary, but among the identified reasons are; incorrectly defined needs, low trust and resistance to change. (Halonen, 2007; Holsapple & Whinston, 1996)

One of the solutions proposed by Hunter (2010) to address the challenges related to information systems and their implementations, is to educate the stakeholders. This can be considered the most difficult task, as there are many levels of stakeholders with different backgrounds. Improving the stakeholder's knowledge regarding the organizational needs and improving the trust in the implemented information systems could potentially reduce the failure rate of implementation projects. The research and development of these types of systems will continue despite the very high failure rates of information systems projects. The potential benefits of a successful implementation can greatly improve an organization's decision-making processes. (Harsh, 2014; Hunter, 2010)

Decision support systems

As described earlier in this paper, the decision-making process is very complex, and there is a substantial amount of research supporting the statement that we humans are not optimal at making decisions, especially when confronted with vast amounts unprocessed or raw information. Druzdzel and Flynn (2002) explored the basics of the systems designed to aid in problem-solving, problem-modeling and the decision-making process. *Decision support systems,* or *DSS* for short, is the term used to describe a type of information system dedicated to actively aid in the decision-making process. (Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996; Sage, 1991; Turban, Aronson. Jay, & Liang, 2007; Zhengmeng & Xingling, 2012)

Decision support systems can be found in every part our modern world, such as corporations, militaries, healthcare, banks, traffic and air traffic control. The term *decision support system* is used to define a plethora of different types of systems. (Bharath & Chennupati, 2013; Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996; Turban et al., 2007; Zhengmeng & Xingling, 2012)

Decision support systems are a sub-branch of information systems. Decision support systems are designed to help the users making decisions by processing information and make suggestions or predictions. Decision support systems are gaining popularity because of how valuable processed data can be to decision makers. (Bharath & Chennupati, 2013; Druzdzel & Flynn, 2002; Zhengmeng & Xingling, 2012)

According to Andrew P. Sage (1991), there are three fundamental components of a decision support system; *database management system, model-based management system* and d*ialog generation* and *management system*. The database management system stores data that is relevant for the decision-making process. The model-based management system contains the algorithms and models that the system uses to process data into tangible information. The dialog generation and management system function as the user-interface and allows the user to access the information stored in the database and process it in the model-based management system. (Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996; Marin, 2008; Sage, 1991; Zhengmeng & Xingling, 2012)

Concept and meaning of decision support systems

A decision support system is an interactive computer-based information system. A decision support system is an information system that utilizes databases, statistical models, decision models, decision rules and the decision makers own knowledge to aid in the decision-making process. The system aids decision makers in specific and complex decision-making tasks and increases the effectiveness of the whole decision-making process. (Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996; Zhengmeng & Xingling, 2012)

Development of decision support systems

The development of decision support systems saw a significant boost during the 1970s and 1980s, and decision support systems were one of the dominant fields of research within the broader field information systems. Several types of decision support systems were developed during this period:

- Problem structuring support systems
- Operations support systems
- Financial management and strategic decision-making
- Group decision support systems
- Executive information systems

According to Liu et al (2009), these types of systems fulfill different roles within an organization. Some systems are dedicated to very specific processes within an organization, while other like the executive information systems are designed to be enterprise spanning systems. These systems are capable of organization wide reporting of key performance indicators, competitive information, news, budget information and more. Highly specialized systems are needed as more data becomes available and problems become more complex, this has resulted in the decline of more traditional decision support systems. (Druzdzel & Flynn, 2002; Liu, Duffy, Whitfield, & Boyle, 2009)

Characteristics of a decision support system

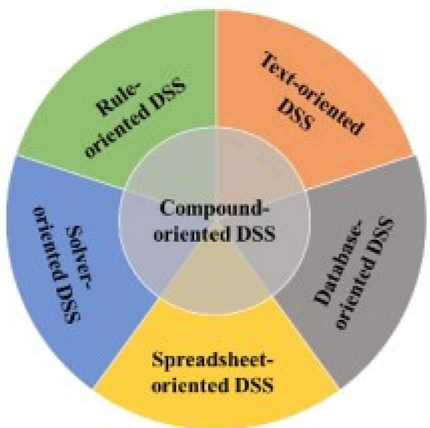
A decision support system is tailor-made for a specific task, but a wide variety of systems fall under the definition of *decision Support System (Druzdzel & Flynn, 2002)*. Every decision support system has its own characteristics, but the following list contains some of the more common traits of a decision support system:

1. Contain large amounts of data.
2. Collect and process from different internal and external sources of data.
3. Interactive and flexible presentation and report generation.
4. Contain both statistical and graphical elements.
5. Perform complex data analysis based on computer models.
6. Support optimization and qualitative approaches, which provides flexibility.
7. Can perform "what if" and result prediction analysis.

(Druzdzel & Flynn, 2002; Hasan, Ebrahim, Wan Mahmood, & Ab Rahman, 2016; Holsapple & Whinston, 1996; Tripathi, 2011)

Different types of decision support system

Decision support systems do not have a clearly defined standard classification, as many systems can be used in the decision support role, while also fulfilling other purposes. Holsapple and Whinston (1996) created a classification chart for decision support systems which is referenced in decision support system literature, but it is not regarded as the global standard.



Picture 7 Holsapple and Winston's Decision support system classification (Hasan et al., 2016)

In Holsapple and Winston's classification chart, there are several types of decision support systems. *Text-oriented DSS* tracks information stored in text format that could be useful in the decision-making process. *Database-oriented DSS* is made up databases, allowing large amount of data to be stored and accessed. When the decision-making process requires graphical modeling and data representation, a *spreadsheet-oriented DSS* can be used. *Solver-oriented DSS* is a system that uses modules or algorithms to aid in the decision-making process, these solvers are designed for specific problem-solving requirements. *Rule-oriented DSS* is an adaptation of the decision-support systems where the system gives the user suggestions on a course of action based on the information available. Some research suggests that the *rule-oriented DSS* is part of the development towards artificial intelligence (Hasan et al., 2016).

When two or more of these classifications are combined, the system can be classified as a *compound-oriented DSS*. The compound-oriented DSS can, according to Zhengmeng and Xingling (2012), be considered the most popular classification of a decision support system and perhaps the best representation of a true decision-support system. (Hasan et al., 2016; Holsapple & Whinston, 1996; Zhengmeng & Xingling, 2012)

Despite the lack of an internationally accepted classification for decision support systems, these systems can be divided into three main categories. These categories are based on the decision support system's purpose and design approach. A *passive decision support system* is a simple support system that aids the decision-making process by presenting information, but the system cannot generate options or solutions. These systems are used to visualize information by using relational databases and models, and the decision maker is responsible for making sense of the information. An *active decision support system* is a complex type of support system that can be used for a variety of different purposes requiring active decision-making assistance. These systems are used by all types of organizations such as, the military, hospitals, banks, air traffic. Active decision support systems are used where decisions and actions must be made during rapidly changing circumstances, such as operating theatres where the medical teams quickly need to respond to changes. A *cooperative decision support system* is a highly interactive support system that generates options and solutions by processing data and sending a suggested course of action to the decision maker. The decision maker can analyze the suggestion from the system, input more variables or make necessary changes and the edited version is reprocessed by the support system for validation. This process can be repeated until a desired outcome is reached. (Hasan et al., 2016; Holsapple & Whinston, 1996; Marin, 2008; Zhengmeng & Xingling, 2012)

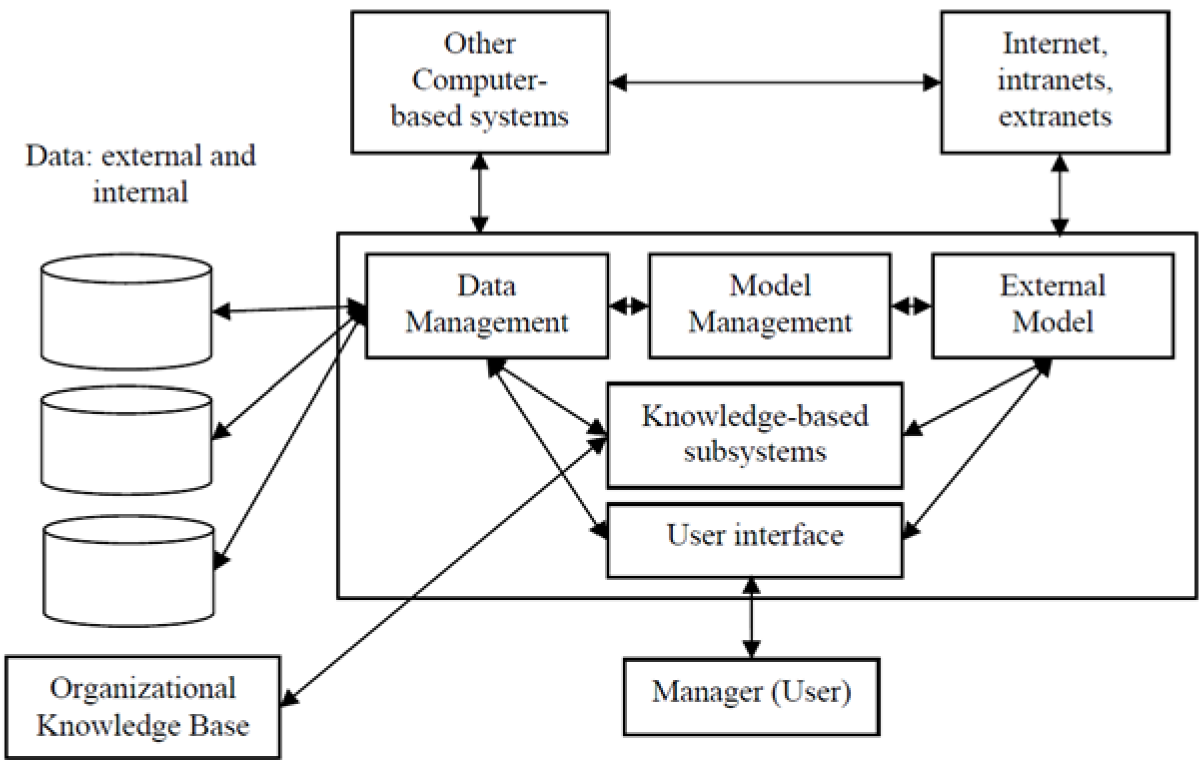
Components of a decision support System

The database or *Database Management System* (DBMS) is the part of the decision support system that contains all the data that are relevant for the class of problems that the support system has been designed to support. The database contains data that the organization has gathered in its relational databases and deemed important for the decision-making processes. There are other sources of data that are being used by the decision support system, such as other internal computer-based systems and a range of other internal and external sources of data. (Druzdzel & Flynn, 2002; Marin, 2008; Zhengmeng & Xingling, 2012)

The task of the model (also known as the *Model-Base Management System MBMS)* is to process data both from internal and external sources into information that is useful for the decision-making process. There are a range of different models in each decision support system, as each part of the decision-making process is broken down into smaller components that are processed in different ways depending on the model required. (Druzdzel & Flynn, 2002; Zhengmeng & Xingling, 2012)

The user interface is the part of the decision support system that allows the decision maker to interact with the rest of the decision support system. The decision maker can interact and request information from the decision support system using actions, the decision support system returns results as presentations in both numerical form and graphs of different types. The user interface is the bridge between the decision maker and the databases, sources of data and the models. The purpose of the user interface is to function as a filter between the mathematical models, datasets and the user. The intended user is a decision maker within an organization who is rarely expected to have knowledge of the inner workings of a decision support system, thus it is important to separate the "noise" of big data from the relevant information that is displayed to the user. (Druzdzel & Flynn, 2002; Zhengmeng & Xingling, 2012)

The final component of the decision support system is the decision maker. The decision support system is not able to function without a user, as the system requires some form of interaction to fulfill its purpose. Some decision support systems require the user to request information, such as passive- and cooperative decision support systems, while active Decision support systems can function by themselves after the initial startup, for example medical support systems that monitor patients' vital signs, as these systems provide a continuous stream of information and suggestions to the medical team. The decision maker is only able to see the results of the mathematical formulas and models, while the decision support system handles all the actual calculations. This approach is designed to aid the decision maker while removing information that is irrelevant from the decision-making process from the user's view. (Druzdzel & Flynn, 2002; Zhengmeng & Xingling, 2012)



Picture 8 Components of a Decision Support System. (Tripathi, 2011)

Picture 8 (Tripathi, 2011) shows the theoretical structure of a decision support system. There are several different depictions of the structure depending on the source one is using.

Information is uploaded to the decision support system from different sources and processed according to the type of data. The structure of a decision support system can vary depending on its intended purpose, but the key components will remain the same regardless of the system.

Organizations and decision support systems

Decision support systems can be embedded into different parts of an organization. How a decision support system is used, depends on the requirements of the organization or department where the system is deployed. Hospitals can have several different decision support systems in use at the same time, for example, systems supporting the overall management of the hospital, patient information systems that aid in the long-term care of a patient, and active clinical decision support systems that are used during surgery. (Bharath & Chennupati, 2013; Druzdzel & Flynn, 2002; Liu et al., 2009; Zhengmeng & Xingling, 2012)

Organizations can benefit from having decision support systems on most, if not all levels of the organizational structure. The largest benefit from decision support systems can be found in the areas where the human decision-making process struggles. Areas where the decision-making process requires large amounts of data, or in areas where decisions must be made quickly based on rapidly changing parameters. (Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996)

There are many different types of decision support systems, and this is what makes it very difficult to define what a decision support system really is. Any system that can aid in the decision-making process can be defined as a decision support system. The literature determines that decision support systems play an active role in the modern world, and that the continued development of these types of systems contributes to improved decision-making processes. (Druzdzel & Flynn, 2002; Holsapple & Whinston, 1996)

Summarizing the literature review

The objective of the literature review is to highlight the difficulties in the decision-making process, and how these difficulties can be overcome using technology. The literature supports the need for information systems to improve the decision-making processes within organizations and defines the systems that are being developed and used for this specific purpose. (Druzdzel & Flynn, 2002; Simon, 1960)

Information systems and decision support systems are designed according to specific organizational requirements. It is difficult to find a generally accepted definition for these systems in the literature, as each author uses slightly different definitions for each system. The core traits of information and decision support systems can be summarized according to Bourgeois (2014), as systems that collect, store, process, filter and distribute data. (Bourgeois, 2014)

3. Application and system development

Introduction to the practical research

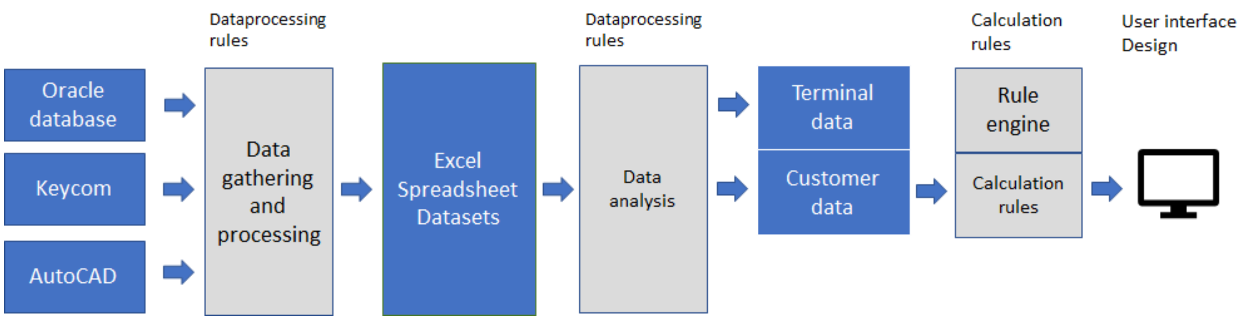
The purpose of this chapter is to go over the different parts that made up the practical application and system development. The research was conducted under a Non-disclosure-agreement (NDA), and the data used for the practical part of the research is sensitive and cannot be displayed in this research paper. All the data presented is scrambled or mocked to give an accurate representation of the data that was available but will not be the actual data used for development of the system delivered to Partel. The information acquired from the different sources of data include actual customer information, phone numbers, geographical information of network terminals and customers.

The first objective of the research process was to analyze the current state of things within Partel, this included determining an area to focus on. It was jointly determined with Partel that the research should focus on the existing copper cable networks and try to determine if the data available to Partel could be used for some form of data analysis process and possibly aid in the decision-making process. The key issue facing Partel at this time was the lack of information to make decisions regarding projects to upgrade the existing copper cable networks to optical fiber networks in the rural areas of Pargas.

Partel knew that upgrading the existing networks in the densely populated areas was a financially sound decision, as there was an adequately high interest from the population to invest in optical fiber connections. The geographical areas with dense populations were reasonably small, which would reduce the costs of construction projects. The problem facing Partel were the rural areas where distances between houses could be far greater and the cost of laying ground cable could be very expensive. Partel determined that focusing the research on these areas would deliver the most value to the company.

Partel did not have access to any dedicated decision support system at the time of the research, and all decisions were made based on information that could be retrieved and processed from different data sources.

Development process overview



Picture 9 Development process visualization

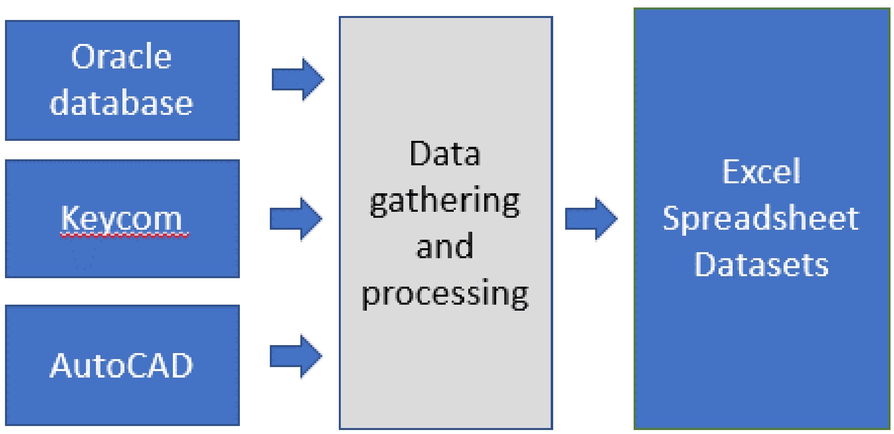
Picture 9 visualizes the different development processes required for the implementation of the proposed system to aid in Partel's decision-making processes.

1. Data gathering and processing
2. Data analysis
3. Rule- and calculation engine
4. User interface design

Each step of the overall process took different amounts of time, and each step was normally revisited several times during the research, as new or improved processes were implemented to meet the evolving demands. As Partel did not have any system or process in place that was comparable to the one designed, it required trial and error to meet the requirements Partel had. Each process is the result of continuous communication with the head of networks at Partel, as he was the most knowledgeable regarding the subject matter, and he was designated as the primary stakeholder for the research, as the goal was to develop a system that would primarily be used by him.

Data gathering and processing

To deliver the most value to Partel, the main task of the research was to identify the cable distances and terminal locations. With this information Partel could calculate the deconstruction cost of each network. This information was considered the most important from a decision-making perspective, as the deconstruction cost was purely a cost with very little return of investment. *Picture 10* visualizes the data gathering and processing from the different sources. Any additional information that could be acquired as a result of the research process would be considered an added benefit and how to best apply this information was discussed with Partel as the information was acquired.



Picture 10 Data gathering process

After the decisions had been taken by Partel regarding the focus of the research, the task was to import the existing data from the data sources to an Excel spreadsheet. Partel has three primary sources of data for the copper cable networks.

- Oracle database
- Keycom
- AutoCAD maps

Partel's oracle database contains a variety of data related to their business, but from this research perspective the *cable pair* data, as it was dubbed, was the most interesting. The *cable pair* data contains relational data of Partel's copper cable networks, including customer-to-terminal connection data, the number of cable pairs in a terminal, the amount of faulty cable and customer specific data. The data imported from the oracle database was described by Partel as being the most accurate out of all their data sources, the only limitation of the data being that it could not be used to effectively aid the decision-making process in its current form.

Keycom is a browser-based mapping tool used by Partel and other internet service providers in Finland. This program is licensed, and the data and the maps are part of the non-disclosure agreement, meaning that the information acquired cannot be displayed in this research paper.

Keycom is used by Partel to visually map and document cable networks. The software can also be used to plan upcoming infrastructure project. Partel has documented the existing copper network in Keycom, but the accuracy and documentation level vary from network to network. Some areas are almost completely mapped and documented and give a fairly accurate picture of how the network is structured. Other networks were documented to a lesser degree, where cables and terminals could be completely missing, reducing the accuracy of the information that could be retrieved. The varying degree of documentation made Keycom an unreliable data source and was mostly used for verification purposes.

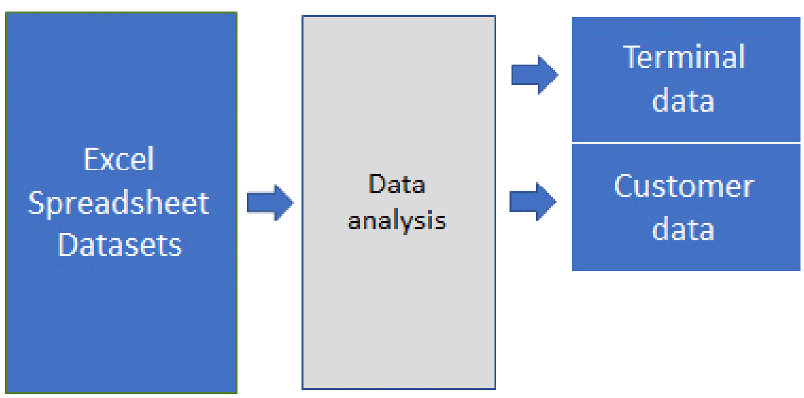
The benefit of Keycom is that a well-documented network can give a clear visual overview of how a network is constructed and connected. A visual overview of a network structure can aid in identifying network bottlenecks and dependencies. If the area is well documented, it contains visual markers for each terminal and the cables that are connected between them. The coordinates of each terminal can also be acquired from this system.

One of the limitations of Keycom is the lack of statistical information regarding the terminals. The only information that can be retrieved is the number of cable pairs, but this information is only available if the user who designed the network in Keycom inserted this information.

AutoCAD is a commercial software used for 2D and 3D designs. Partel had used AutoCAD maps to document the infrastructure of their copper cable networks, and these maps contained some important information that was not stored in other systems. The only useful information that could be obtained from the AutoCAD maps was data regarding network cable lengths between terminals, and what type of cables were being used. All the relevant information was manually extracted from the AutoCAD maps and moved to Excel.

The AutoCAD maps only served as a minor source of data, and this information could be retrieved to some extent from Keycom. Comparing the information from AutoCAD and Keycom was determined to be an acceptable approach to verify the accuracy of the information. Partel also had one expert in the network area, and this expert was consulted whenever information from two sources of data was contradicting each other, or when information was completely missing. When errors like this occurred, the data was analyzed together with the expert and all sources of data were updated with the new information.

Data analysis



Picture 11 Data processing rules

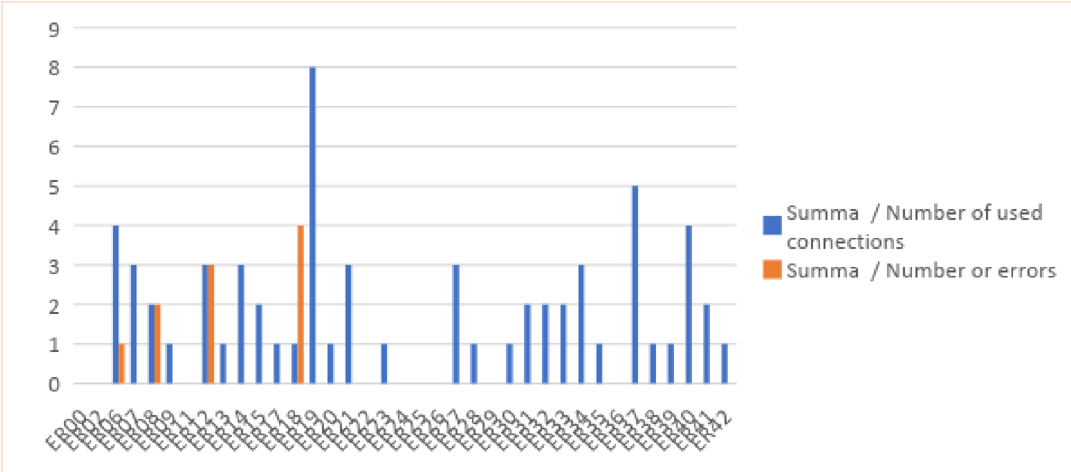
The data analysis process shown in *picture 11* includes all the processes where data was structured into the two primary datasets; *Terminal data* and *Customer data*. The first step in the data analysis process for each Excel file created was the *terminal data analysis*, as the terminal data contained most of the useful data for the system to function.

Terminal data analysis

The goal of the terminal data analysis was to gather and process the relevant data for each terminal in the local networks. Using data from the different data sources, information regarding different local networks can be acquired down to terminal level. The terminals can be sorted into groups containing all the terminals from one area based on the alphanumeric terminal ID. The terminal data was structured as following:

- TerminalID
    - # cable pairs
    - # used cables
    - # errors
    - X - coordinates
    - Y - coordinates

The data displays how many cable pairs are available to one terminal, which would be the terminal's theoretical max capacity. The number of used cable pairs shows the current usage of cable pairs for a specific terminal. Errors indicate the number of malfunctioning cable pars in this terminal, one important thing that was revealed at an early stage was that malfunctioning cable pairs could be tracked throughout the network, so any malfunctioning pair located in one of the core terminals could potentially show up further down the line in the network, giving an indication to were the problem could possibly originate. The Y and X coordinates gave the geographical location of the terminal in the field. Using the statistical information for each terminal ID in a local network, it was possible to generate a simple graph in Excel visualizing the statistical information to the user, see *Table 1*.



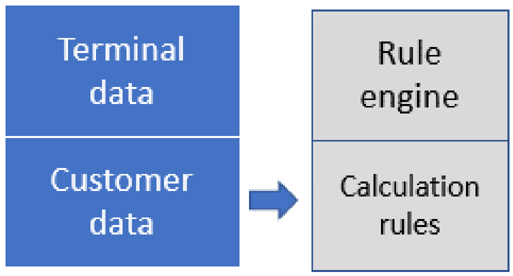
Picture 12 Overview of the number of users and errors

Picture 12 shows how many users are connected to a terminal in blue, while the orange indicates how many faulty cable pairs there are per terminal. This information on its own can be used in the decision-making process, for example for risk analysis and determining the financial important of each terminal. This graph does, however, not display any relation between the terminals and based on this graph it is not possible to create a network map that could be used for more advanced decisions. Terminals are not connected in a numerical specific order, for example; terminal number 1 is not necessarily connected to terminal number 2 and terminal 2, in turn, might not be connected to terminal number 3. Two consequently numbered terminals can be connected to each other, but this cannot be guaranteed.

The network is structured as a web, with a few terminals branching out from the main network terminal, followed by one or more terminals connected to each in the first layer, and continuing outwards for an unknown number of jumps. Determining what order the terminals are connected to each other is required for any detailed analysis of the cable networks.

Rule engine and calculation rules

Each Excel file contains a rule engine that is connected to the different datasets.



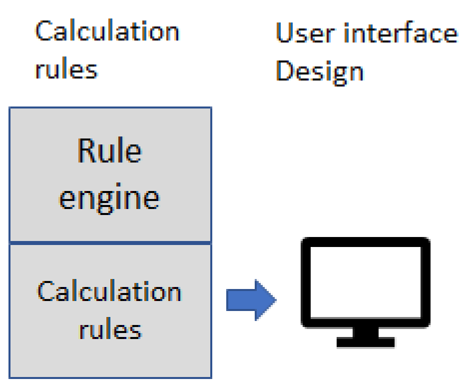
Picture 13 Calculation rules

The rule engine was developed as part of the research, and the requirements and scope of the research was continuously. The rules include how data should be structured in the different datasets, how the calculations should be done and what parameters to use. Some of these rules were defined by Partel. The INDEX MATCH function in Excel is among the rules used for the research, and how this function works will be described later in this paper in the section; *Excel function example*.

User interface design

The user interface is the part of the decision support system that allows the decision maker to interact with the system. Therefore, the user interface must be designed in such a way that the intended user can easily interact with it. (Druzdzel & Flynn (2002), Zhengmeng & Xingling (2012),

The user interface design for the system went through several different versions. The difficulty in designing the user interface for the system was that neither the requirements or the intended user was defined during the start of the design process. Several different versions were developed before a version was accepted by Partel.

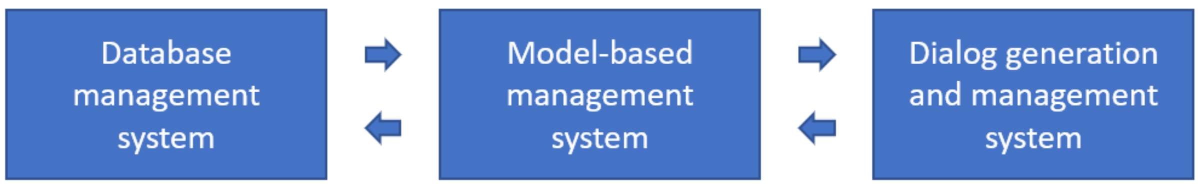


Picture 14 Calculations to user interface

The goal of the user interface design was to allow Partel's head of networks to a retrieve relevant information easily from the datasets. The information relevant to the user's work was cable distance, basic customer density, statistics and a breakdown of the different cable types in an area. The final user interface design will be presented in *Dialog generation and management system - Partel implementation.*

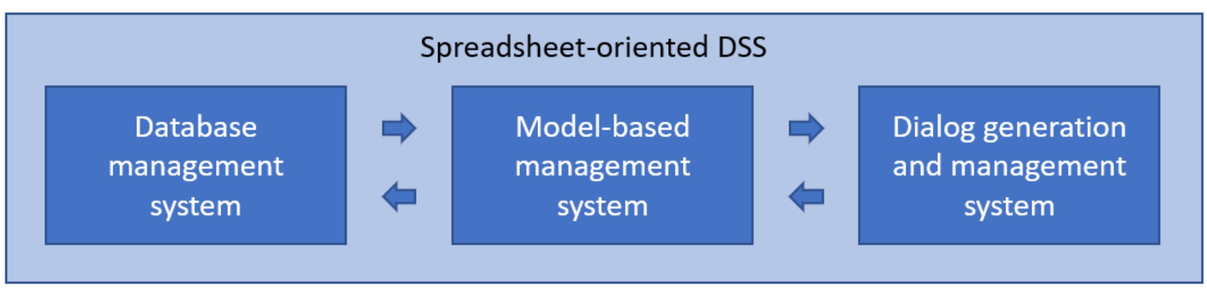
Type of decision support system

In the theoretical part of this paper, it was stated that Andrew P. Sage (1991) had identified three fundamental components of a decision support system; *Database management system, Model-based management system* and *Dialog generation and management system*. This will be used as the structure for the practical part of this paper, and the different development processes will be described in their own sections.



Picture 15 System overview

The type of decision-support system chosen for the Partel implementation was a *Spreadsheet-oriented DSS*, as these types of systems are used when the decision-making process requires the use of modeling tools and graphical data representation (Holsapple & Whinston, 1996). Microsoft Excel is a software used by Partel, and all identified users had some knowledge of how to use Microsoft Excel, and this allowed for data to be visualized without the use of a more sophisticated and potentially expensive software.

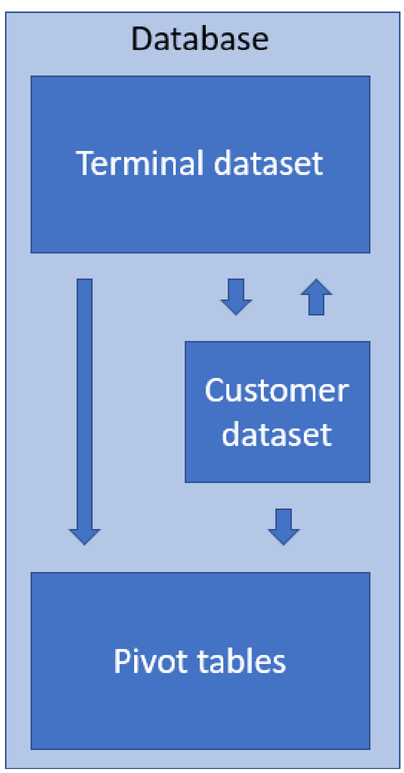


Picture 16 Spreadsheet oriented DSS

The practical part of the research was done as a small-scale budget system and proof of concept, which meant that no dedicated databases or model-based systems were designed. All the relevant data and processes are contained within one Excel file, and one Excel file only contains data relevant to a specific local network.

Database management system - Partel implementation

The database contained within each Excel file hold only the relevant information from one local network, therefore, there is no cross communication or comparison between networks. The main dataset is the *terminal dataset* that contains the relevant information for most of the required calculations. There is, however, some data transference between the *terminal dataset* and the *customer dataset*. The data contained within the customer dataset allows for the creation of a network map, information which is not contained in Partel's terminal oracle database. The data transferred between the terminal dataset and the customer dataset is coordinate and calculated cable distance data.



Picture 17 Database

The information from the datasets is compiled into pivot tables, allowing the user interface to interact with the data without changing or editing the datasets. This approach was chosen based on trial and error. Calculations and actions done by the user only manipulates the pivot tables, and any action can easily be undone.

Terminal dataset

The terminal dataset contains all the relevant statistical and geographical data gathered from the different data sources. Most of the data stored in the terminal dataset was copied straight from the other data sources. Some of the copying processes were done manually, as there was no way of moving data from the AutoCAD or Keycom maps to the Excel files via system commands. The terminal dataset required manual work due to the different data structures between the oracle database, Keycom and AutoCAD.

Cable box	Number o	Number o	Number o	X - Coordi	Y - Coordi	Estimated	Active cus	All custom	Current in	ADSL coun
ER00		0		2370XX	66923YY	0	0	0	0	0
ER02	20	0	0	2370XX	66923YY	0	0	0	0	0
ER06	10	4	1	2370XX	66923YY	0	1046	1657	140	4
ER07	10	3	0	2370XX	66923YY	0	383	607	94	2
ER08	20	2	2	2370XX	66923YY	0	32	32	47	1
ER09	21	1	0	2370XX	66923YY	0	114	1983	12	0
ER11	10	0	0	2370XX	66923YY	0	0	0	0	0
ER12	30	3	3	2370XX	66923YY	0	1489	3939	82	2
ER13	20	1	0	2370XX	66923YY	0	556	781	12	0
ER14	10	3	0	2370XX	66923YY	0	630	1640	82	2
ER15	10	2	0	2370XX	66923YY	0	267	1853	82	2
ER17	10	1	0	2370XX	66923YY	0	126	257	12	0
ER18	10	1	4	2370XX	66923YY	0	705	1786	35	1
ER19	26	8	0	2370XX	66923YY	0	1878	3583	281	7
ER20	20	1	0	2370XX	66923YY	0	225	314	12	0
ER21	30	3	0	2370XX	66923YY	0	631	2057	94	2
ER22	20	0	0	2370XX	66923YY	0	0	0	0	0
ER23	10	1	0	2370XX	66923YY	0	225	1374	12	0
ER24	10	0	0	2370XX	66923YY	0	0	0	0	0
ER25	10	0	0	2370XX	66923YY	0	0	0	0	0
ER26		0		2370XX	66923YY	0	0	0	0	0
ER27	20	3	0	2370XX	66923YY	0	450	1178	105	3
ER28	10	1	0	2370XX	66923YY	0	73	458	35	1
ER29	10	0	0	2370XX	66923YY	0	0	430	0	0
ER30	10	1	0	2370XX	66923YY	0	350	831	35	1
ER31	10	2	0	2370XX	66923YY	0	234	459	47	1

Table 1 Terminal database example

The terminal dataset shown in *table 1* contains data from the different data sources as well as, data from the customer dataset. The data provides a statistical overview of the terminals and allows the user to analyze each terminal individually or the network as a whole.

Start	X	Y	End	X	Y	Core cable
ER07	2370XX	66923YY	ER06	2369XX	66923YY	89.05055
ER00	2370XX	66923YY	ER07	2369XX	66923YY	25
ER07	2370XX	66923YY	ER08	2369XX	66923YY	220
ER00	2370XX	66923YY	ER09	2369XX	66923YY	537
ER09	2370XX	66923YY	ER11	2369XX	66923YY	60
ER15	2370XX	66923YY	ER12	2369XX	66923YY	592.466
ER12	2370XX	66923YY	ER13	2369XX	66923YY	366
ER13	2370XX	66923YY	ER14	2369XX	66923YY	704.4693
ER00	2370XX	66923YY	ER15	2369XX	66923YY	2600
ER40	2370XX	66923YY	ER17	2369XX	66923YY	344
ER19	2370XX	66923YY	ER18	2369XX	66923YY	714
ER21	2370XX	66923YY	ER19	2369XX	66923YY	450
ER21	2370XX	66923YY	ER20	2369XX	66923YY	790
ER06	2370XX	66923YY	ER21	2369XX	66923YY	886
ER20	2370XX	66923YY	ER22	2369XX	66923YY	790
ER22	2370XX	66923YY	ER23	2369XX	66923YY	463.2462
ER25	2370XX	66923YY	ER24	2369XX	66923YY	200
ER24	2370XX	66923YY	ER25	2369XX	66923YY	200
ER00	2370XX	66923YY	ER26	2369XX	66923YY	277
ER29	2370XX	66923YY	ER27	2369XX	66923YY	138
ER29	2370XX	66923YY	ER28	2369XX	66923YY	98.49365
ER30	2370XX	66923YY	ER29	2369XX	66923YY	107.0047
ER26	2370XX	66923YY	ER30	2369XX	66923YY	127
ER33	2370XX	66923YY	ER31	2369XX	66923YY	222
ER33	2370XX	66923YY	ER32	2369XX	66923YY	132

Table 2 Terminal connection data

Table 2 visualizes the table where data regarding cable distances between terminals is stored. The table is used for verification of data from the different data sources, as the data was manually imported to the table from the AutoCAD, Keycom and the oracle database. The imported cable distances were compared to calculated distances between the terminals, to verify the accuracy of the data. If the calculated and imported distances were relatively similar, the data was kept in its original form. If the distance between the two values varied or the imported cable distance was shorter than the calculated distance, then the data was doubled-checked, and the correct cable distance was calculated and updated in the dataset.

Customer dataset

The customer dataset is a supporting dataset containing customer data and customer distribution in a local network. The dataset also provides information regarding how terminals are connected to each other. Each customer has information how it is connected to the network in the form of a network connection pattern. The network connection pattern can be used to track the customer from the central terminal to the final terminal that connects to the customer. This information could be used in the creation of a network map for the network. The connection pattern for each customer is removed from the final version of each Excel file, as the data was only used for manually creating the network map and served no other purpose. The following data that is stored in the final version of the excel files is; customer IDs, coordinates, cable distances and estimated income from the subscription.

Subscri	Box ID	Status	Appartme	House ID	X -coordir	Y - Coordi	Estimated	Unknown	Unused ca	ADSL chec	Subscripti	Current income
PAR060	ER06	1	2369	41	2369XX	66923YY	67	0	0	1	35	35
PAR060	ER06	1	2370	58	2369XX	66923YY	298	0	0	1	35	35
PAR080	ER06	1	2366	24	2369XX	66923YY	169	0	0	1	35	35
PAR090	ER06	1	2372	76	2369XX	66923YY	511	0	0	1	35	35
4586201	ER07	1	2367	31	2369XX	66923YY	113	0	0	1	47	47
5E+06	ER07	1	0	0	2369XX	66923YY	225	225	0	0	12	12
PAR120	ER07	1	2365	22	2369XX	66923YY	45	0	0	1	35	35
5E+06	ER08	1	2364	12	2369XX	66923YY	32	0	0	0	12	12
PAR030	ER08	1	2364	12	2369XX	66923YY	32	0	0	1	35	35
5E+06	ER09	1	192	13	2369XX	66923YY	114	0	0	0	12	12
5E+06	ER12	1	2283	99	2369XX	66923YY	1147	0	0	0	12	12
5E+06	ER13	1	3088	84	2369XX	66923YY	556	0	0	0	12	12
5E+06	ER14	1	2284	101	2369XX	66923YY	61	0	0	0	12	12
PAR060	ER14	1	2281	74	2369XX	66923YY	197	0	0	1	35	35
PAR070	ER12	1	0	0	2369XX	66923YY	225	225	0	1	35	35
PAR080	ER14	1	3225	7	2369XX	66923YY	372	0	0	1	35	35
PAR120	ER12	1	2278	5	2369XX	66923YY	118	0	0	1	35	35
4586313	ER15	1	2345	10	2369XX	66923YY	129	0	0	1	47	47
PAR140	ER15	1	2346	12	2369XX	66923YY	138	0	0	1	35	35
5E+06	ER17	1	5349	108	2369XX	66923YY	126	0	0	0	12	12
PAR070	ER18	1	5459	78	2369XX	66923YY	705	0	0	1	35	35
4586212	ER19	1	2375	150	2369XX	66923YY	412	0	0	1	47	47
5E+06	ER19	1	2376	151	2369XX	66923YY	81	0	0	0	12	12
4587011	ER19	1	2379	169	2369XX	66923YY	219	0	0	1	47	47
PAR030	ER19	1	5458	6	2369XX	66923YY	163	0	0	1	35	35
PAR050	ER19	1	3073	13	2369XX	66923YY	202	0	0	1	35	35

Table 3 Customer database example

In *table 3,* edited data from the customer dataset is displayed. Each row contains the unique customerID, which terminal the customer is connected to and the data imported from the data sources as well as the processed data.

The purpose of the customer dataset is to store customer data and what terminals they are connected to. The dataset also provides data for income and cable distance calculations, as well as, containing formulas such as *unknown cable distance*. These values are generated by the rule engine to make the data available to other systems and to fill in caps in the data wherever it is missing.

The *unknown cable distance* is calculated based on a mean average of the known customer cable distances in an area. The mean average is calculated based on the local networks average, and not average of all Partel's networks. This approach was approved by Partel, and it is required because some of the customers geographical locations have not been added to the oracle database.

The income fields are populated by an Excel function that matches the customer's ID to the different products that can be connected to it. The income value is imported from the user interface where the user can change it.

The customerID is generated based on the customer's products, were a customer can belong to one of three customer types; phone customer, ADSL customer and ADSL + Phone customer. A phone customer's ID is the phone number, an ADSL customer has an ID containing "PAR" followed by seven digits, and a customer with both ADSL and phone products have an ID that combines both the phone number with the ADSL ID separated by a *slash (/)* symbol. The system contains a function that searches for distinct features that fits into one of these three customer types, and then adds the correct value.

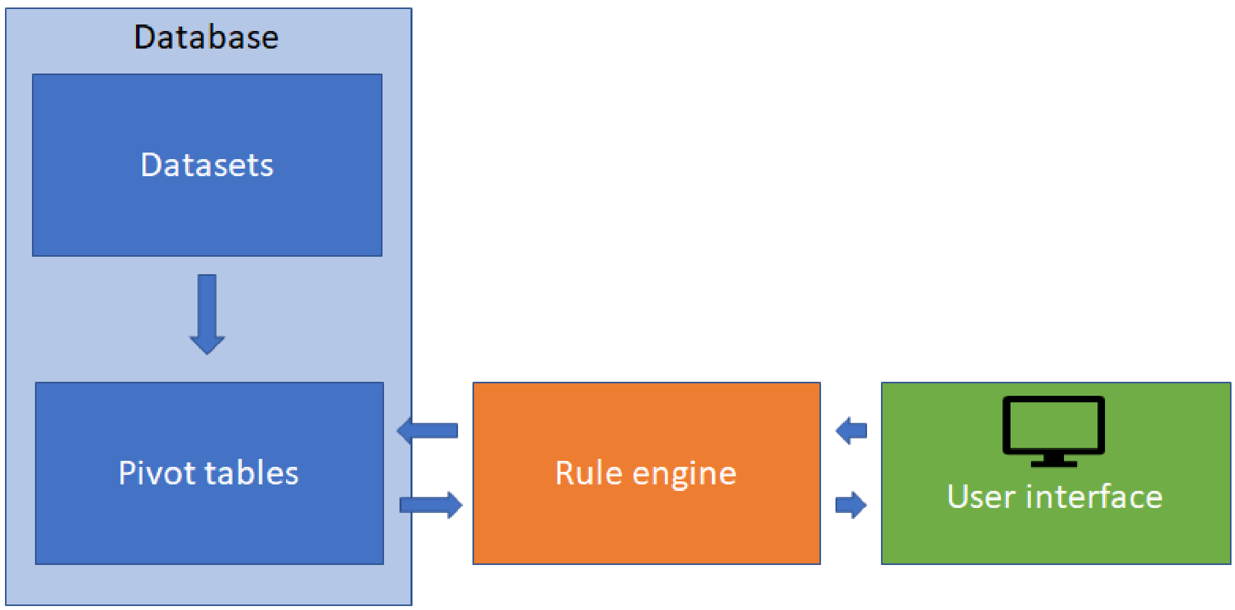
Subscripti	X -coordir	Y - Coordi	Box ID	X -coordir	Y - Coordi	Estimated distance
PAR06001	2369XX	66923YY	ER06	2369XX	66923YY	67
PAR06005	2369XX	66923YY	ER06	2369XX	66923YY	298
PAR08005	2369XX	66923YY	ER06	2369XX	66923YY	169
PAR09004	2369XX	66923YY	ER06	2369XX	66923YY	511
4586201/F	2369XX	66923YY	ER07	2369XX	66923YY	113
PAR12005	2369XX	66923YY	ER07	2369XX	66923YY	45
4586297	2369XX	66923YY	ER08	2369XX	66923YY	32
4586261	2369XX	66923YY	ER09	2369XX	66923YY	114
4544396	2369XX	66923YY	ER12	2369XX	66923YY	1147
4586253	2369XX	66923YY	ER13	2369XX	66923YY	556
4588222	2369XX	66923YY	ER14	2369XX	66923YY	61
PAR06007	2369XX	66923YY	ER14	2369XX	66923YY	197
PAR08000	2369XX	66923YY	ER14	2369XX	66923YY	372
PAR12005	2369XX	66923YY	ER12	2369XX	66923YY	118
4586313/F	2369XX	66923YY	ER15	2369XX	66923YY	129
PAR14003	2369XX	66923YY	ER15	2369XX	66923YY	138
4586277	2369XX	66923YY	ER17	2369XX	66923YY	126
PAR07006	2369XX	66923YY	ER18	2369XX	66923YY	705
4586212/F	2369XX	66923YY	ER19	2369XX	66923YY	412
4586296	2369XX	66923YY	ER19	2369XX	66923YY	81
4587011/F	2369XX	66923YY	ER19	2369XX	66923YY	219
PAR03003	2369XX	66923YY	ER19	2369XX	66923YY	163
PAR05017	2369XX	66923YY	ER19	2369XX	66923YY	202
PAR06011	2369XX	66923YY	ER19	2369XX	66923YY	76
PAR09000	2369XX	66923YY	ER19	2369XX	66923YY	161
PAR11005	2369XX	66923YY	ER19	2369XX	66923YY	564
4586278	2369XX	66923YY	ER21	2369XX	66923YY	204
4587773/F	236326	6692194	ER21	2369XX	66923YY	382

Table 4 Customer connection data

The customer dataset also contains a distance calculation table, shown in *table 4.* The table is generated from unique customer locations and the corresponding terminals. The distance calculation formula will be explained later in this chapter, *see Customer cable distance calculation* for the example. The information gathered from this table is imported into the terminal dataset as a sum of all the customer distances for each terminal.

Pivot tables

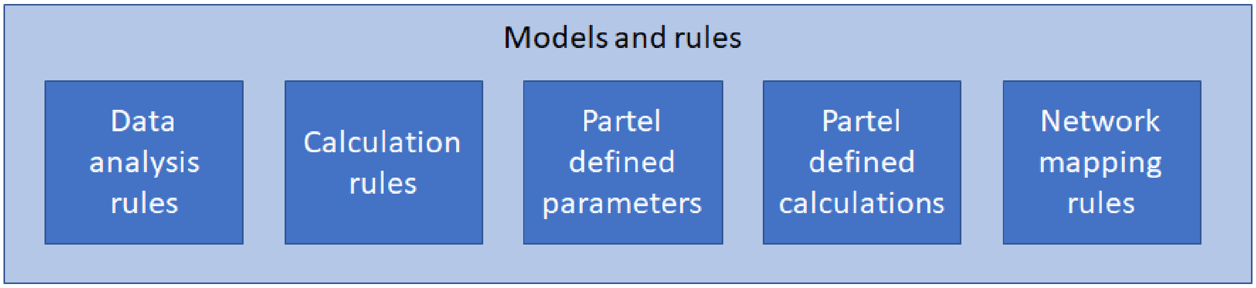
The pivot tables for each Excel file are created from the data in the *Terminal* and *Customer datasets*. The reason for using pivot tables is to allow the user to interact with the data using inputs and the *Excel slicer* function in a user-friendly manner, while not changing the actual data contained in the datasets.



Picture 18 Data usage example

Picture 18 visualizes how the data is moved from the datasets to the pivot tables. When a user wants to interact with the data, the commands passes through the rule engine which uses different functions to calculate and fetch data from the pivot tables, returning the data to the user interface as comprehensible information.

Model-based management system - Partel implementation



Picture 19 Models and rules

The model engine that was built into each network Excel file contains five main models or rules. *Data analysis rules* apply to all forms of processes that require data to be transferred or processed in a way to make it useful for the system. The main data analysis rules were manual processes of how data was best moved from Patel's data sources to the Excel files, and how the data was structured in the datasets to allow the data to be used by other parts of the system.

Calculation rules incorporate all the different automatic and manual calculations. The system has several integrated calculations that allows the user to interact with the data and extract the information that was required, such as cost calculations. Other calculations were done manually as part of the process to setup the Excel files. These calculations are, for example the different distance calculations between the terminal and the customers.

Partel defined parameters and *Partel defined calculations* include all the different conditions that were delivered by Partel, such as how the distance between the customers and the terminal should be calculated, and all the formulas for calculating the number of cable pillars in the field, cable type distributions and how to manage missing coordinate information for terminals. These rules were delivered by Partel and verified in small scale tests were the result of the system output were compared against actual information from the field.

Network mapping rules is a manual process with defined sets of rules how to generate a network map from the different datasets and calculations available. This part required the use of more advanced Excel functions such as *INDEX MATCH*, which is explained in a later chapter. Some trial and error was required to determine how to generate a visual representation of the network's layout.

Example components

The following section will present three of the components that makes up the models and rules section in each Excel file.

Terminal cable distance

The cable distances between terminals could be acquired from Partel's three data sources, the oracle database, Keycom and AutoCAD maps. Calculating the distance between terminals required the geographical coordinates from the oracle database. The distance between the two coordinate points were calculated and an additional 30 percent distance was added to account for geographical obstacles and construction limitations. The 30 percent additions to the cable distance was a value given by Partel, as this was the value used by the network people for similar calculations.

The calculated distance was compared to the distances acquired from the AutoCAD maps. If the difference between the two distances was marginal, then the longer distance was used into the dataset as the distance used for measurements. If there was a substantial difference between the two measurements, the Keycom map was used to analyze the distance. All distance differences were measured together with the network expert at Partel and all data sources were corrected with the new data.

Customer data analysis rule

The goal of the customer data analysis is to gather geographical information regarding the customers so that customer cable distances to terminals could be calculated, as this information did not exist in any of Partel's sources of data. Additional information of interest is what types of customers are connected to a terminal, ADSL or phone customer, as this information could be used for a financial analysis of the network.

The customer coordinates stored in the Oracle database use the *Finnish horizontal coordinate system (KKJ)* (Finnish horizontal coordinate systems.2017), which is different from the GPS coordinates stored for terminal locations. This required a conversion of all customer coordinates from KKJ to the GPS coordinates. This conversion was done together with Partel's head of networks to verify that the conversion was done correctly.

Customer cable distance calculation

The connection between customers and the terminals and the geographical locations are available in the oracle database, which enabled the use of the formula for calculating the distances between two points:

$$d^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2$$

This formula gives the distance between two points. This is, however, not the correct distance of a cable between a customer and a terminal. To compensate for geographical obstacles, the distances were extended by 30 percent on the request of Partel. This enabled for the estimation of all customer cable distances with an acceptable margin of error according to Partel.

During the distance calculation process, it was discovered that several customers share the same geographical location, meaning that all these customers are sharing a cable between the location and the closest terminal, rather than having individual cables for each connection. Using this knowledge, it is possible to use the *remove duplicates* function in Excel to remove duplicate locations from the dataset. This required the creation of a secondary data table that only contains the unique geographical locations and use the distance calculations to their respective terminals. The customer cable distances were summed up and added as a value for each respective terminal in the terminal dataset.

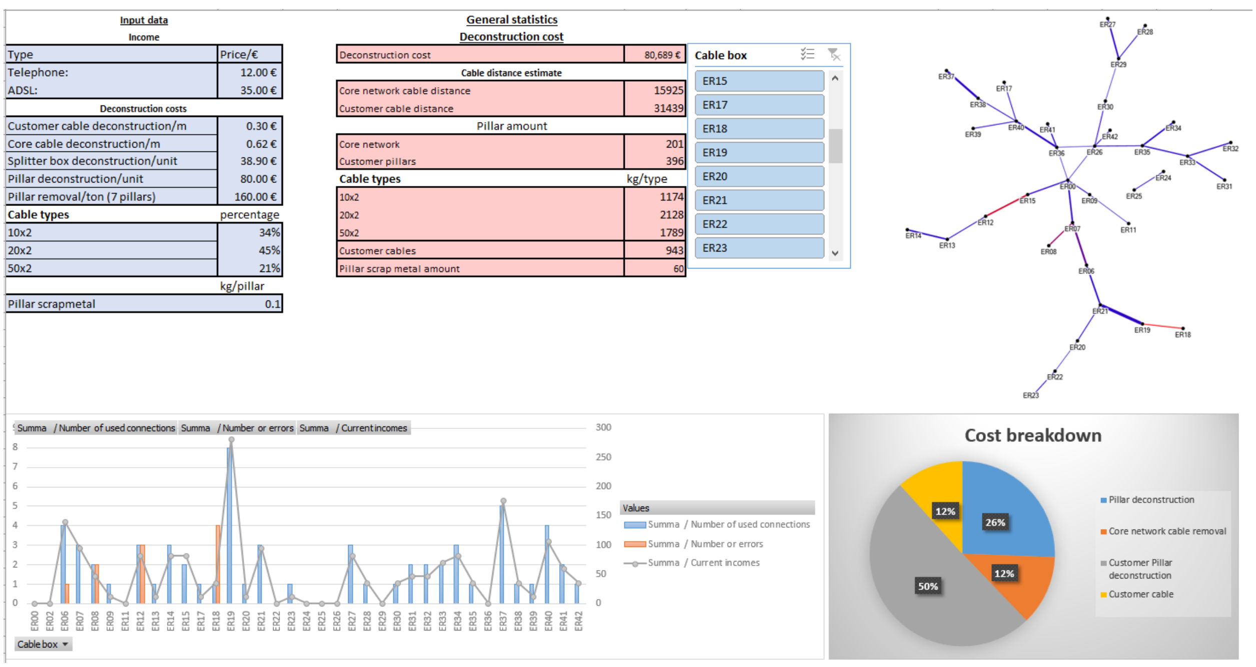
Some customers were missing their geographical location in the dataset. To overcome this issue, it was agreed with Partel that a *mean average* for the cable distances in the network would be used to determine the cable distance for these locations. The number of customers missing this information varied from network to network, but Partel decided that a rough estimate was acceptable. This method results in inaccuracies in the dataset, but because the development was aimed at providing an estimated value based on data retrieved from existing data sources, it was deemed acceptable.

Dialog generation and management system - Partel implementation

The user interface design went through several different iterations. Different information was displayed, and varying degrees of user interaction was evaluated. Partel finally decided on a version which was designed to calculating the deconstruction cost of a local network.

The Excel file was designed to do all the calculations in the background, and only allow the user to interact with the data from one sheet in the Excel file.

The design would best fit the description of a *passive decision support system* described by Druzdzel and Flynn (2002). The system has a defined model that it uses to display existing information. It will not actively make decisions but it displays information based on the data in the datasets and the user's inputs. *Picture 20 final UI design* shows the final design for the spreadsheet-based decision support system developed for Partel.



Picture 20 Final UI design

The user interface is made up of six different components, two that allows the user to interact with the data, and four components that visualize information.

Input data

Income

Type	Price/€
Telephone:	12.00 €
ADSL:	35.00 €

Deconstruction costs

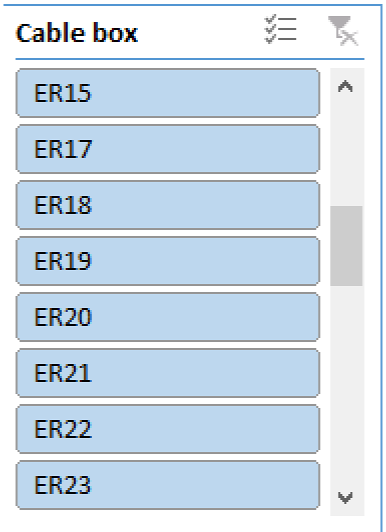
Customer cable deconstruction/m	0.30 €
Core cable deconstruction/m	0.62 €
Splitter box deconstruction/unit	38.90 €
Pillar deconstruction/unit	80.00 €
Pillar removal/ton (7 pillars)	160.00 €

Cable types	percentage
10x2	34%
20x2	45%
50x2	21%

	kg/pillar
Pillar scrapmetal	0.1

Picture 21 Input data

The input data field shown in *picture 21* allows the user to change the costs structure and cable type distribution. The information from these fields is connected to calculation fields in the different pivot tables, allowing the user to calculate estimated deconstruction costs. The reason why the user needs to be able to change the cost structure, is because each deconstruction project would be priced individually.



Picture 22 UI cable box selection slicer

The *Cable box selection slicer* shown in *picture 22* allows the user to select one or more terminals from the network. The slicer is connected to the different pivot tables, allowing the rules and calculations to display information from a selected area of the network, or the entire network.

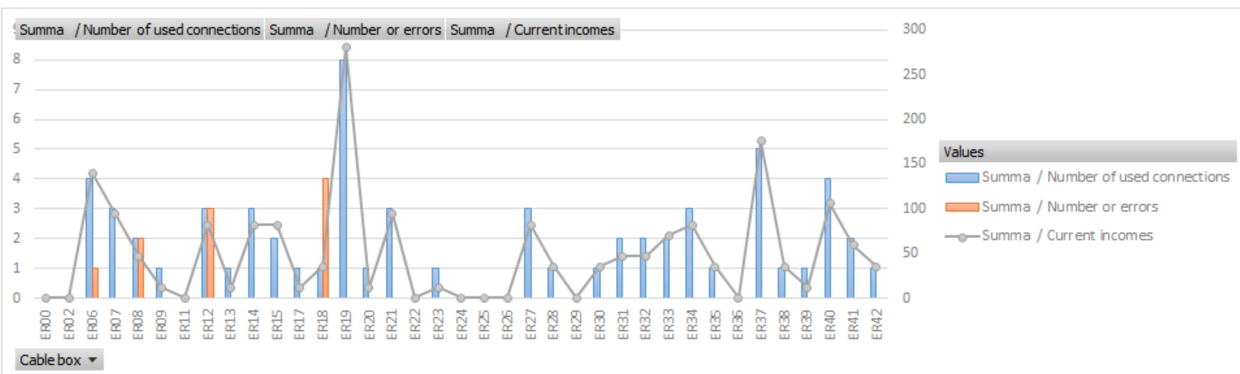
General statistics	
Deconstruction cost	
Deconstruction cost	80,689 €
Cable distance estimate	
Core network cable distance	15925
Customer cable distance	31439
Pillar amount	
Core network	201
Customer pillars	396
Cable types	kg/type
10x2	1174
20x2	2128
50x2	1789
Customer cables	943
Pillar scrap metal amount	60

Picture 23 Statistics for deconstruction costs

The general statistics, shown in *picture 23,* is part of the user interface and displays the output from the different rules and calculations embedded in the Excel file. These cells are locked so that the user cannot tamper with the underlying calculation functions.

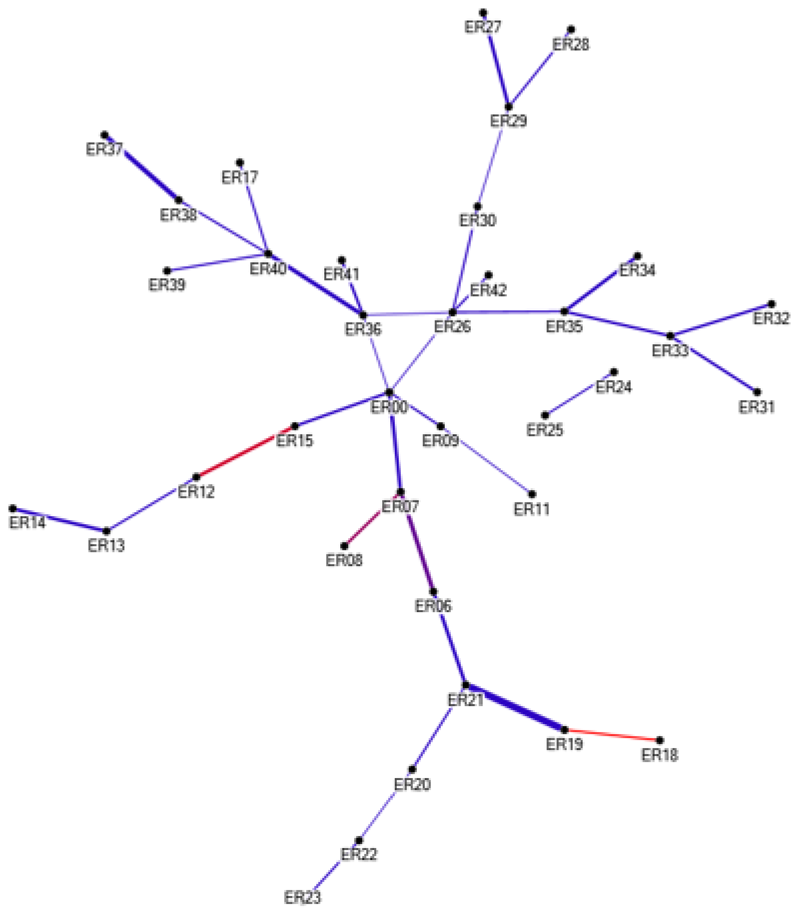
The main purpose of this module is to give an estimated deconstruction cost based on the data contained within the Excel file. Different components of the copper cable network have different costs, and potential profits when sold, so displaying the distribution of customer cables and core network cables is of interest for Partel's head of networks.

All the information displayed is based on the user's terminal selections, so the user can either choose to display the deconstruction costs for the entire network or focus the selection on a part of the network that might need upgrading or repairs.



Picture 24 Terminal statistics graph

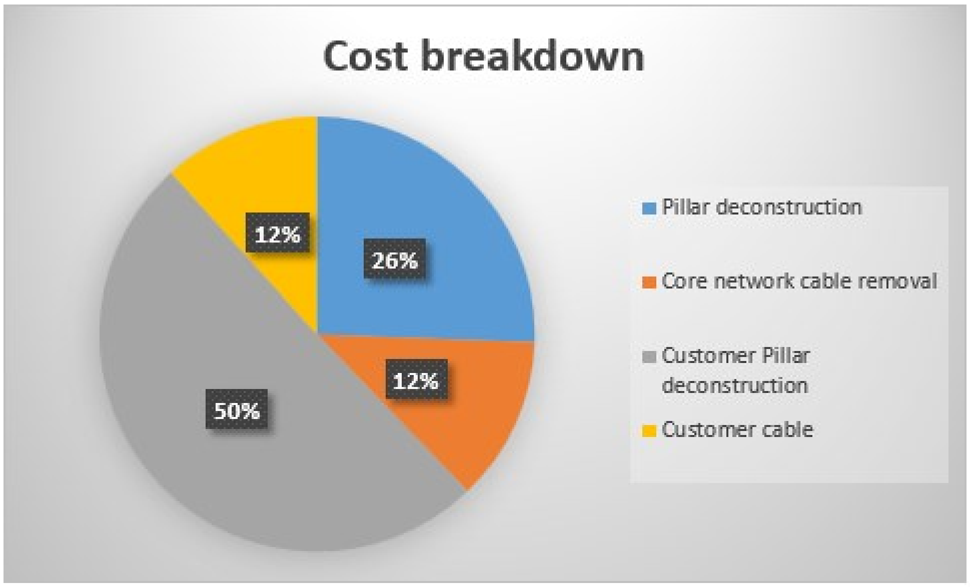
The terminal statistics graph gives the user a visual indication of the state of a network. The number of active connections and customers are displayed per terminal, as well as, the number of faulty cables. This information helps the user decide how to filter the data in the interface. The income from each terminal is also displayed in the graph as a gray line. This graph is connected to the *Cable box selection slicer*, giving the user an additional tool to filter information in the user interface.



Picture 25 Network map

The *picture 25 network map* is a static representation of the local network. The network map is created with the information from the terminal and customer datasets. The network map displays how the different terminals are connected to each other in the network, however, it is not a representation of how the network looks geographically. The distances between and the geographical locations of terminals are not represented in this network map.

The network map has three attributes, one being the network connection model. The second attribute is the color schema, were the colors goes from a deep blue to a clear red and these colors represents the state of the cables between terminals. The information from *Terminal statistics graph* is represented in the color schema, deep blue indicating no faulty cables and a clear red indicating that this section has statistically more errors compared to the rest of the network. The last attribute is the width of the connections between terminals. This is a visual representation of how many active customers there is connected between the terminals.



Picture 26 Cost breakdown pie chart

The *Cost breakdown pie chart* is the last module in the user interface, and this module will display the different costs types in a selected area. This module is interactive and will change depending on the user's selection in the *Cable box selection slicer*.

User interface design summary

The user interface was very appreciated by Partel's head of networks, as it allows for a very easy interaction with the data. The main purpose of the system was to aid in the decision-making process and was never intended to give a 100% accurate information. The intention was to give the user an overview of the state of a network and allow for some interaction and manipulation of the data. The design is not based on any theoretical model. It was built based on the needs stated by Partel during the development process.

Excel function example

The research process for Partel required the use of several advanced Excel functions, and this chapter will highlight one of the most important ones, and how it can be applied in look up processes in Microsoft Excel.

Arranging data using Microsoft Excel

There are different functions in Excel that can be used to search for values. One of the most commonly used functions is the VLOOKUP, which will search for a given value in a column and return the first value found that matches the search criteria. This is a very rudimentary function which can only be used for the most basic of searches.

The INDEX MATCH function is regarded as one of Excel's most useful search functions as it, unlike the VLOOPKUP can be used for more complex searches using multiple criteria to find the right match. The INDEX MATCH is often referred to as a function, even though it is a combination of two other functions in Excel, the INDEX and the MATCH.

The INDEX function written in Excel:

=INDEX(range, row_num)

The INDEX formula searches through a range of cells, and selects the value defined by the row_num part. In the example 1 *picture 27* below, the function searches through the range C3:C5, and returns the value in the second row, in this case 8958013.

	A	B	C	D
1				
2		State	population	Population rank
3		California	39250017	3
4		New Jersey	8958013	11
5		Nevada	2940058	34
6				
7		Formula result	8958013	
8		Formula: =	INDEX(C3:C5,2)	

Picture 27 Function example 1

The MATCH function written in Excel:

=MATCH(lookup_value, Lookup_range, [match_type])

The MATCH function looks through a range of cells and returns the position or row number of the selected cell range that corresponds with that Lookup_value. The [match_type] part of the function can be used to specify one of the following criteria:

- 1 -Lesser than
- 0 - Exact match
- -1 – Greater than

The function follows a TRUE (1) or FALSE (0) process and by looking through each value in the cell range, it returns either a 1 or a 0 depending on if the criteria fits the Lookup_value and the [match_type].

	A	B	C	D
1				
2		State	population	Population rank
3		California	39250017	3
4		New Jersey	8958013	11
5		Nevada	2940058	34
6				
7		Formula result	1	
8		Formula: =	MATCH("California",B3:B5,0)	

Picture 28 Function example 2

In *picture 28 function example 2* the MATCH function searches for the value California in the cell range B3:B5, the function is asked to look for the exact match. The function returns 1, which corresponds to cell B3, which is the position of the word California in the cell range that was defined in the function.

Combining the INDEX and the MATCH functions explained earlier will result in the following function:

= INDEX (range, MATCH (lookup_value, lookup_range, [match_type])

By expanding on the previous examples, it is possible to create a function that returns a desired value from one range, by comparing its location to one or more values in other cell ranges.

	A	B	C	D
1				
2		State	population	Population rank
3		California	39250017	3
4		New Jersey	8958013	11
5		Nevada	2940058	34
6				
7		Formula result	California	
8		Formula: =	INDEX(B3:B5,MATCH(10,(D3:D5),1))	

Picture 29 Function example 3

In *picture 29*, the function searches for the value in cell range B3:B5 that corresponds to the position determined by the MATCH function in the cell range D3:D5. The match type is Lesser than and the value was set as 10. The result that was found is 3 in cell D3, meaning that the INDEX function returns the value found in cell B3, which is California.

This example is a very basic explanation of the INDEX MATCH functions potential uses, as it can be expanded upon to match several different ranges and returning the cell position from a larger matrix.

4. Analysis and results

The results from the research were very appreciated by Partel. The initial plan was for a six-month research and development process, but as the first prototypes of the network Excel files were presented, Partel decided that they wanted similar Excel files for all their local copper cable networks, extending the research and development process to one and a half years. This paper presents the results of the extended research.

The Excel files served as a part of Partel's decision-making process, allowing the head of networks to do very basic estimates for both local networks and smaller parts of each network. The information gathered from the Excel files then served as support for different project decisions on where and how to allocate resources to achieve the best results.

The system can only make calculations based on the information retained within the datasets, meaning that unknown or undocumented information will not be considered and thus make the system less accurate than calculating the distances and pillars in the field.

The advantage of the system was that the time required to both produce an Excel file, and display the information to the stakeholders was relatively short. The development process for all the models and rules took up most of the development time, and the only time-consuming process as part of each Excel development was the data gathering, as each network had different levels of documentation, and were also of widely different sizes. Some networks contained around twenty, while others could have closer to forty terminals.

Analysis of the application

General benefits of the system

The system was developed as part of the research project and was implemented into each Excel tool aid in Partel's decision-making process by reducing the work required to make informed decisions regarding the existing copper cable networks. Each decision maker at Partel has access to the same easy-to-use interface that will display all the data gathered for that specific area.

Information previously had to be processed from the different data sources before it could be used in the decision-making process. All this data is now contained within the Excel files and can be accessed at any time by any user who has access to them.

The research also proved the benefit of having accurate data, as this has a direct correlation to how well a system of this type can do estimations. The system's main benefits were work reduction and increased speed in the decision-making process, meaning that decision makers can make informed decisions quickly, rather than spend time doing data processing each time a decision has to be made.

Small scale tests

During the development process, Partel wanted to do a small-scale test of the system. This test involved the development of a small-scale Excel file for a specific area of a local network that would then be verified by people in the field.

The area selected is under NDA and cannot be revealed, but it was a small densely populated area in the outskirts of the Pargas downtown area. The test was intended as a proof of concept for the system, and the Excel file was developed following the rules and models developed for all the other local cable networks.

The result from the test was that the difference between the field verification and the system was less than 10%, indicating that the models and rules applied to the system were giving fairly accurate information regarding cable distances and number of pillars in a selected network. The system also gave additional information that could not be retrieved by a person on the ground, such as the condition of the cables, estimated cable lengths and customer information.

The resulting test convinced Partel to commission the implementation of more local cable network files, giving Partel an increased awareness of the state and potential costs of their existing infrastructure assets.

Additional perceived benefits

As mentioned earlier in the paper, Keycom was lacking information regarding networks. During each analysis phase additional information regarding the network was discovered, and all the Keycom maps were updated with the new information.

Another additional benefit from working with Microsoft Excel was the discovery of more advanced functions. One of these functions was used to develop a model for network mapping of future projects. The method is based on the distance calculations between the customer and terminals, and the discovery of how to use array functions in Excel to calculate and determine the shortest distance from a set of coordinates.

This tool was specifically designed for Partel's head of networks, as he oversees the design of new networks. The method required the GPS coordinates of potential customers and the coordinates for the terminals that would make up the network. The model would calculate which terminal would be the closest to each customer using the array function:

```
{=LOOKUP(1,1/FREQUENCY(0,MMULT((CELL_RANGE-
COORDINATES)^2,{1,1})),CELL_RANGE)}
```

This array function will look through a cell range containing all the coordinates for all the potential terminals, calculate the distance between each terminal and the given customer coordinates, and return the smallest value.

This tool was created outside of the research project and is the result of experience, and knowledge gained from working with other functions in Excel for over a year. The tool was designed as a template where the head of networks could insert the available information regarding customer and terminal locations in a new area and based on the output estimate what type of terminals would be needed to meet the demand in the area.

System as a decision support system

Decision support systems are often designed as custom solutions for specific needs. The more specialized a system is, the better it will be able to complete that task. Decision support systems are designed with one or more benefits in mind but finding the specific benefits for specific systems is difficult, as these systems are not widely distributed and can provide market advantages to the owner. Using the literature as a reference, it is possible to determine a set of benefits that decision support systems can provide. These benefits are summarized from the literature and can occur under different definition names depending on what sources one reads. (Druzdzel & Flynn, 2002; Filip et al., 2017; Holsapple & Whinston, 1996; Pomerol & Adam, 2008)

General benefits from a decision support system implementation

Improved efficiency is one of the benefits that can be found from implementing a decision support system. Tasks that require a lot of time or are simply too demanding for a human to complete can be allocated to a decision support system. The benefits can be improved time savings, as the system is able to output the information faster than a human would be able to extract and process data from the data sources.

Improved accuracy is another benefit that could also be part of the *improved efficiency* but will be considered as a benefit of its own in this context. The decision support system can have access to vast amounts of data and using different models, the system can output very accurate information. The level of the accuracy depends on the system design and the accuracy of the data contained within the system.

Improved communication is a benefit that can result from the implementation of a decision support system. This benefit stems from the output and access to the system by the decision makers. The information available to all decision makers is outputted in the same format and this can be assumed as "the truth" for this specific case, removing much of the debate that can stem from different people compiling a report regarding the same issue.

Competitive advantage is one of the main reasons why it is difficult to find specific information about decision support systems, as the systems, if implemented correctly will hold a clear competitive advantage on the market. The more data and models that are available to an organization, the better the organization can understand the market that they operate in, given that the system is designed in such a way as to benefit the organization in this matter.

Reduced cost is a benefit that can sometimes be contributed to the implementation of decision support systems. An organization might experience reduced costs after implementing a decision support system. This can be a result of more accurate information, more effective decision-making processes and reduced resource allocation to activities that support the decision-making process.

Increased decision-making process accuracy is the main goal of a decision support system. The reason why an organization implements a decision support system is to improve the accuracy of their decision-making processes, or simply put, make the right decisions at the right time. This benefit is dependent on both the system's design and the decision maker's willingness to trust the information delivered by the system.

Benefits from Partel's decision support system

The Partel system was developed with the goal of improving the *decision-making process accuracy*. The system gave Partel the ability to look at the relevant data from all their data sources in one place and based on this, make decisions. This benefit was achieved on delivery, as Partel did not have a system or process in place that would allow for easy access to relevant data for this type of decision-making tasks.

The system can also be considered to deliver *improved efficiency* as the user does not have to collect and analyze the data again. The system has all the relevant information for the existing copper cable networks, and the user can easily access information relevant to the deconstruction process for these networks.

Improved communication can also be considered as a benefit of the system implementation, as all decision makers within Partel will have access to the same information.

Improved accuracy is clearly a benefit from the system, as the whole system has the latest information regarding geographical locations and cable distances that can be retrieved from the different data sources. The accuracy of the cable distances and number of cables can, however, not be guaranteed, as the system displays information that has at some point been manually inputted into one of the data sources and must be treated as such. The output of the small-scale tests was positive, but this output cannot be guaranteed for larger areas, or areas that required more estimations to be done based on missing information.

Cost reduction is a partial benefit, as the time it takes to compile information required for a decision has been reduced. It is unclear if a comprehensive analysis of this scale would have been done for the existing networks outside of this project, and this has therefore been considered an increased cost from this research perspective.

Competitive advantage cannot be considered a benefit from this system, as Partel holds a monopoly on the cables in Pargas and do not have to concern themselves with a competitive advantage from this system. Any competition that would be introduced to the physical network market would also not benefit from information regarding existing networks, as they would have to construct their own.

Review of research questions

This chapter is aimed at reviewing the research questions raised at the beginning of the research and evaluate if the research was able to answer these questions.

How can information systems aid in the decision-making process?

The primary question for the research presented in this paper is how the theories and possible practical applications of information systems could aid Partel in their decision-making process. This was the core question raised before the study began, as it was not clear what the eventual focus or outcome of the research would be.

The different research options were all focused on processing data into useful information that would aid in the different optical fiber projects. Eventually, it was agreed that the focus of the research would be to use existing data and attempt a data analysis process that would output useful information for Partel.

In the case of Partel, the decision-making process was aided by the implementation of a very rudimentary decision support system, which is a type of information system dedicated to aiding in decision-making processes. The decision support system was designed using Microsoft Excel and used manual data processing, where data was moved and processed from the different data sources manually.

The result of the research and the subsequent work resulted in a tool that gave Partel an overview of each local copper cable network that was part of the scope. The decision support system helps the decision makers at Partel make *informed decisions* regarding copper cable networks. Every individual who is part of the decision-making process has access to the same information provided by the Excel tool, meaning that all the relevant information from the data sources is available and can be easily accessed for the intended purpose.

The Excel tool helps Partel make decisions based on information about the copper cable networks, rather than making assumptions or relying on *ad hoc* data analysis when a decision must be made.

Can the data gathered by Partel aid in the decision-making process?

Partel had three main sources where data was stored, and one of the main research questions was whether this data would be suitable for processing to enable it to be reused in the decision-making processes.

The first question raised when looking through the data was really: what kind of information can be retrieved? The data contained within Partel's different data sources were related to both existing customers and the different local cable networks. The type of data was determined to be most useful for the deconstruction process that was in progress at Partel. The data contained all the information regarding cable connections, cable statuses and all the relevant information to both geographically located customers and terminals.

The result from the research and subsequent work indicates that the chosen research approach was successful. The Excel tool, using data collected by Partel, was able to estimate with an acceptable margin of error both cable distances and the number of pillars for the network that was part of the small-scale test. The system had an error rate off less than 10% for the small-scale test, and even though this number can increase for larger networks, the information provided to the decision makers was still determined to be useful for Partel.

The conclusion for this research question is that data gathered by Partel could be used to aid in the decision-making process and help Partel to make more *informed decisions*. The more accurate the data, the better the estimates became, so there is a clear correlation between data accuracy and estimations.

Can a low-cost decision support system be developed based on the existing data?

Partel is a small internet service provider, which limits the financial options available to the company when it comes to investing in dedicated systems. Investing in a dedicated decision support system can be expensive but more accurate estimates are difficult to come by, as these types of systems are generally developed based on a customer's specific needs and this results in most decision support systems being unique.

As the research and consequent development was done as part of a master's thesis work, the costs were comparatively low compared to branded systems of the same type. The assessment of the system delivered to Partel indicates that it was possible to deliver a functional tool to aid in the decision-making process, and at a relatively low cost.

The cost for the research and the subsequent work was kept low, as this was a master's thesis work. The exact cost for the total period is undisclosed, but the initial research was done over a four-month period for a fixed monthly cost, and the subsequent work for Partel was done on an hourly basis where work was done both on the existing Excel tools and other tasks that were useful to Partel at the time.

The whole project involved no additional acquisitions of licenses for new software, nor any additional hiring of experts or major resource allocations from other parts of the company. The cost structure involved the monthly and subsequent hourly pay for the researcher, and access to a company computer and workstation.

Open research questions and future research

The conclusion from the research leaves no fully open research questions, as it was possible to deliver a low-cost decision support system using existing data to help Partel make informed decisions related to the deconstruction of copper cable networks.

Further research and development would be suggested to focus on creating a direct connection between the SQL databases and the Excel tool, allowing for a real-time update of the datasets and optimizing the Excel tool.

It is, however, questionable if a continued effort would be cost effective, as the primary goal of the research was achieved, and additional benefits might come at a higher development cost in the future. One question that should be taken from this research is how the planning and estimation process could be as automated as possible. Is it possible to develop a system that could plan the construction of a completely new local cable network using geographical coordinates and some other parameters?

5. Discussion

The research done for Partel follows the theoretical examples presented in this paper very well. At the start of the research, Partel was having difficulties in making decisions based on the data available to them. All the data available to Partel at the time was relevant and could aid in the decision-making process, but the main difficulty was in how the data was structured and it was not readily available in a form that could be used by all stakeholders. The theories laid down by Herbert A. Simon helped in the initial stages of the research, as he highlighted the difficulties faced by many organizations. Using this information, it was possible to analyze Partel's situation and approach it in a structured manner, while allowing for the unknown factors to be addressed later in the project rather than attempting to solve them as part of the initial stages.

The theories regarding information systems and decision support systems laid the groundwork for the system developed for Partel. Partel's implementation is loosely based on the different concepts of decision support systems, but it is developed as a solution specifically for Partel's needs and economic situation. A more advanced version of the system could possibly be developed with different subsystems working to process the data, which was done manually during the research, but this would most likely involve a very expensive investment by Partel.

The design approach resulted in a very specialized tool that is aimed at doing a few tasks well and, based on the feedback from Partel, the system has been well received and fulfills a purpose in their decision-making process. There are no recommendations for future development of the tool, as it is aimed at giving statistical information about local networks that will be decommissioned and replaced with optical fiber networks.

The suggestion given to Partel would be to store more information in the oracle database, which could aid in future decision-making processes. Similar methods to the one used for this research could be applied as a cost-effective solution.

The research allowed for the development of other tools for Partel, of which the tool for connecting customers to a planned network was the most well received, as the tool could speed up the initial decision-making process by removing most of the manual tasks related to planning the customer-to-terminal connections and giving rough estimates on cable and pillar requirements for the construction project.

6. Svensk sammanfattning

Beslutsstödsystem Partel tillämpningen

Målet med studien var att genomföra en analys av tillgängliga data från Partel, för att avgöra om de var möjligt att utgående från denna data skapa ett så kallat beslutsstödsystem.

Partel är ett litet telefon- och internetoperatörsbolag vars verksamhet är koncentrerad till Åbolandsregionen i sydvästra Finland. Under 2015 var Partel fokuserat på att uppgradera sina existerande kopparkabelnätverk, som användes för både telefon- och internettrafik, till modernare optiska fiberlinjer. På grund av Partels begränsade tillgångar var de viktigt för företaget att allokera sina resurser så effektivt som möjligt, för att nå många potentiella kunder inom ramen för varje uppgraderingsprojekt. Analysarbetet blev fokuserat till tre av Partel utvalda områden.

När analysarbetet påbörjades hade Partel svårt att använda den tillgängliga informationen i sina datakällor för att stöda beslutsprocessen, eftersom de inte fanns utarbetade modeller för dataanvändningen, och ingen mall för att ställa upp informationen på ett användarvänligt sätt. Tillsammans med Partels verkställande direktör, utvecklingschef och nätverkschef bestämdes de att analysarbetet skulle fokusera på att utnyttja existerande data för att skapa ett verktyg som kunde stöda Partel i beslutsfrågor relaterade till kopparkabelnätverken. Målet var att genom olika processer analysera data för att bedöma om de var möjligt att utveckla ett så kallet beslutsstödsystem.

Beslutsstödsystem är en undergrupp till den mycket större gruppen av informationssystem som används inom de flesta områden av vår moderna värld. Beslutsstödsystem är system som enbart används till att stöda beslutsprocesser inom olika former av organisationer där mängden tillgänglig information är stor och komplex att en människa inte är kapabel att uppfatta eller behandla den på ett effektivt sätt. Beslutsstödsystem har implementerats inom många olika typer av organisationer, som till exempel inom försvarsmakten, banksektorn och vården, för att nämna några exempel. Beslutsstödsystem är ofta skräddarsydda för att möta väldigt specifika behov inom olika organisationers beslutsprocesser, och kan därför variera i design. Druzdzel och Flynn (2002) menar dock att de flesta beslutsstödsystem har några gemensamma kännetecken, såsom lagring av stora mängder information från både interna och externa källor. Beslutsstödsystem är interaktiva verktyg som tillåter användaren att behandla lagrade data, skapa rapporter och visualisera information. Alla beslutsstödsystem bygger på olika beräkningsmodeller för att producera den information som användaren önskar, och de är därför viktigt att lagra noggranna data som möjligt. (Druzdzel & Flynn, 2002; Hasan, Ebrahim, Wan Mahmood, & Ab Rahman, 2016; Holsapple & Whinston, 1996; Tripathi, 2011)

Teorierna som utgör grunden för analysarbetet bygger huvudsakligen på forskning av Herbert Alexander Simon. Han var en amerikansk ekonomiforskare och statsvetare, vars forskning och tankar har bidragit till utvecklingen av flera moderna forskningsområden, såsom artificiell intelligens, beslutsfattande, problemlösning, informationssystem och beslutsstödsystem. Simon hade en såpass stor inverkan på flera områden att Lewis (1991) noterade att 75 % av alla manualer relaterade till informationssystem grundade sig på Simons tankar. (Lewis, 1991)

Simons teorier indikerar att vi som människor är dåliga på att fatta informerade beslut. Trots att beslut utgör en väsentlig del av vår vardag, är informerade beslut inte normen, utan personer väljer vanligen att förlita sig på intuition eller en så kallad ”magkänsla”. Vår oförmåga att fatta beslut utgående från stora mängder information har lett till utvecklingen av olika system för att stöda beslutsfattaren i dessa processer. Dessa system faller under benämningen informationssystem, som är en stor grupp av it-system designade för att samla, lagra, hantera och distribuera information. Till denna grupp hör beslutsstödsystem eller decision support systems (DSS) på engelska, vilka är system specifikt utvecklade för att stöda i beslutsfrågor inom olika organisationer. (Druzdzel & Flynn, 2002; Langley, Mintzberg, Pitcher, Posada, & Saint-Macary, 1995; Lewis, 1991; Parnas & Clements, 1986; Herbert Simon, 1962; Herbert A. Simon, 1960)

Analysarbetet för Partel fokuserade på tre huvudfrågor:

- Kan informationssystem stöda beslutsprocessen?
- Kan Partels existerande data användas i beslutsprocessen?
- Är de möjligt att skapa ett billigt beslutsstödsystem från insamlade data?

När analysarbetet påbörjades hade Partel tre olika datakällor för information relaterat till deras kopparkabelnätverk, en SQL-databas, ett webbaserat verktyg för grafisk representation av nätverken och äldre AutoCAD-kartor. Den första fasen av analysarbetet var fokuserad på att sammanställa all data från dessa källor till en databas, för att sedan bedöma ifall de var möjligt att utveckla ett beslutsstödsystem utgående från data.

Insamlade data var tillräckligt omfattande för att tillåta utvecklingen av ett rudimentärt beslutsstödsystem, och tillsammans med Partels VD, utvecklingschef och nätverkschef bestämdes de att analysarbetet skulle specifikt fokusera på kostnaderna relaterade till existerande kopparkabelnätverk, där den viktigaste frågan var hur mycket de skulle kosta att riva dessa nätverk för att göra utrymme för nya optiska fibernätverk. Eventuell ny information skulle även uppdateras i datakällorna samt andra eventuella fördelar skulle beaktas.

Analysarbetet gjordes huvudsakligen i Microsoft Excel, eftersom licensen fanns tillgänglig hos Partel, och Microsoft Excel är ett användarvänligt verktyg som var bekant för de tilltänkta användarna på Partel. Informationen från de olika datakällorna exporterades till Excelfiler där behandlingsprocessen utfördes. Processen gick ut på att jämföra informationen från de olika datakällorna, för att förkasta felaktig information och filtrera bort information som sparats flera gånger. När informationen var korrigerad och verifierad sorterades den till kundspecifik information och terminalspecifik information, för att kunna skapa en nätverkskarta och kunna göra estimeringar på kabeldistanser, antalet kabelstålpar, kundantal per terminal, inkomster och nedmonteringskonstader. Eftersom analysarbetet gjordes i nära samarbete med Partels nätverkschef, utvecklades målet kontinuerligt för att möte Partels behov baserat på den nya information som blivit tillgänglig.

Resultatet av analysarbetet var ett rudimentärt beslutsstödsystem som tillåter användaren att ta del av relevanta data på ett användarvänligt sätt. Bild 20 visar hur användargränssnittet för systemet ser ut. Användaren har tillgång till en visuell representation av all data som finns tillgängliga för ett specifikt kopparkabelnätverk, och kan utgående från denna data få estimeringar om nedmonteringskostnader, kabellängder, antal aktiva kunder, inkomster, mängden trasiga kabelpar och kostnaden för att nedmontera nätverket.

För att verifiera hur noggrant systemet var gjordes en jämförelse i liten skala, där noggrann information från ett utvalt område samlades in av en person på fältet och sedan jämfördes med systemets estimeringar. Målet var att se hur noggrant systemet kunde räkna ut mängden kabelstålpar som existerade i området. Resultatet var att skillnaden mellan systemets estimeringar och informationen var mindre än 10 %, vilket indikerade att uträkningsmodellerna var tillräckligt noggranna för Partels behov. Utöver informationen om hur många kabelstålpar som fanns tillgängliga gav systemet även information om kablarnas tillstånd, estimerade kabellängder och typer av kunder. Partel bestämde sig att beställa ett analysarbete för alla kopparkabelområden som inte var kartlagda.

Systemet stöder Partels nätverkschef i beslutsfrågor, där information kan presenteras snabbt och i ett format som inte tidigare var möjligt. Systemet är designat för att stöda beslutsfattarna i ett tidigt skede av beslutsprocessen, där de är viktigt att få en indikation om eventuella kostnader, men där slutsumman inte ännu behöver beaktas.

Utöver de mål som fanns för undersökningen producerades även ett verktyg för att stöda nätverkschefen i planeringsarbetet av nya optiska fibernätverk. Systemet utvecklades på sidan om analysarbetet, med målet att ta tillvara lärdomar för att stöda andra delar av beslutsprocessen. Systemet som utvecklades hjälpte nätverkschefen att estimera vilka kunder som skulle kopplas till vilka terminaler, baserat på kundernas distans till de planerade terminalerna i det nya nätverket.

Som sammanfattning av forskningsfrågorna kan informationssystem stöda beslutsprocessen. Baserat på det teoretiska materialet var de möjligt att analysera Partels situation och önskemål, och med hjälp av existerande data producera en modell för hur data kunde behandlas och presenteras på ett användarvänligt sätt. Data som var tillgängliga för Partel var tillräckligt omfattande för att stöda utvecklingen av ett beslutsstödsystem. Även om behandlingen av data var tidskrävande resulterade arbetet i ett system som var lämpat för att stöda beslutsprocesserna hos Partel. Arvodena för arbetet var relativt låga än om motsvarande system och arbeten skulle utföras av andra leverantörer. De är dock osannolikt att Partel skulle ha investerat i ett liknande system från en it-leverantör, och därför tillkom de kostnader för Partel som inte skulle ha uppstått utan analysarbetet. Analysarbetet visade även vikten av noggrann insamling och lagring av data, eftersom de mest tidsödande aspekterna av analysarbetet var att sammanställa data till ett behandlingsbart format, och att uppdatera existerande datakällor.

Systemen som utvecklades är baserade på de teorier och modeller som finns. De kan stöda beslutsfattarna i frågor om existerande kabelnätverk, samt stöda i planeringen av nya nätverk. En framtida forskningsfråga skulle vara om de är möjligt att inom ramen för ett pro gradu-arbete utveckla ett system som skulle klara av att planera ett helt nytt kabelnätverk med acceptabla kostnads- och materialestimeringar.

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